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QUALITY INSPECTION TEST, DEMONSTRATION AND EVALUATION REPORT FOR HIGH RELIABILITY LASER POLARIZERS

CDRL SEQUENCE NO. D002

REVISION OR

PREPARED FOR: U.S. ARMY ERADCOM
FORT MONMOUTH, NJ 07703-5307

CONTRACT NO: DAAK20-85-C-0137

24 FEBRUARY 1988

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ABSTRACT

This report presents the results of the evaluation of 50 High Reliability Laser Polarizers to fulfill part of the requirements for Phase III of Contract No. DAAK20-85-C-0137.

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1.0 TEST PLAN OVERVIEW

1.1 Scope

This document describes the results of the evaluation of 50 High Reliability Laser Polarizers (HRLP) manufactured by Litton Airtron Laser Electro-Optics Group for the U.S. Army ERADCOM, Contract Number DAAK20-85-C-013. The test equipment and procedures used in this evaluation followed closely those described in Product Assurance Test, Demonstration and Evaluation Plan For HRLP (CDRL D001) to verify conformance to requirements in Litton Laser Systems' Laser Polarizer Specification, Rev. G.

1.2 Test Plan

The inspection/test sequence used in this evaluation provides a logical and economical plan required to accept production High Reliability Laser Polarizers. This sequence is shown in Figure 1.2 Polarizer Inspection/ Test sequence.

The majority of the inspections/tests in Figure 1.2 were performed on a 100% sampling basis. Certain tests for economical reasons, were performed on a sampling lot size based on 2.5% AQL for inspection Level II, as described in MIL-STD-105, or on only one sample. The extent of individual inspection/ test is illustrated in Table 1.2, HRLP inspection/test list.

1.3 Applicable Documents

This report has been prepared to the extent possible, in accordance with the following documents:

- Contract Number DAAK20-85-C-0137
- Quality Inspection Test, Demonstration and Evaluation Report, DI-R-1724
- Test Reports, Preparation of, MIL-STD-831

The following documents form a part of this report to the extent specified herein:

- Product Assurance Test, Demonstration and Evaluation for High Reliability Laser Polarizers, CDRL D001, Rev. A.
- LLS' Laser Polarizer Specification, Rev. G.

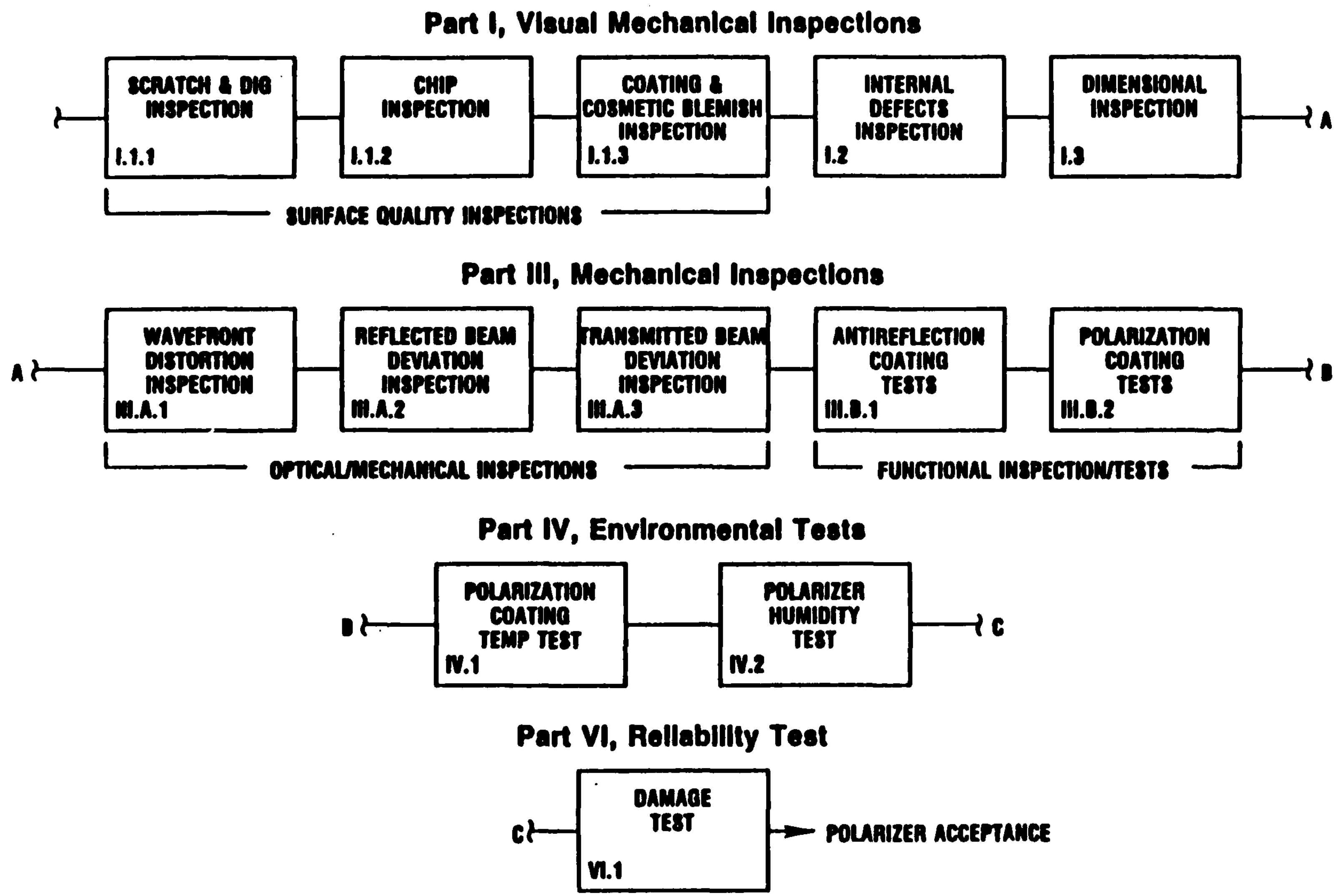

Figure 1.2

POLARIZER (HRLP)

INSPECTION/TEST SEQUENCE

TABLE 1.2 HRLP INSPECTION/TEST LIST

PART	CDRL D001 PARAGRAPH REFERENCE	TITLE	INSPECTION/TEST BASIS
I	NA	VISUAL MECHANICAL INSPECTIONS	CATEGORY TITLE
	I.1	SURFACE QUALITY INSPECTION	CATEGORY TITLE
	I.1.1	SCRATCH & DIG INSPECTION	ALL UNITS
	I.1.2	CHIP INSPECTION	ALL UNITS
	I.1.3	COATING AND COSMETIC BLEMISH INSPECTION	ALL UNITS
	I.2	INTERNAL DEFECTS INSPECTION	ALL UNITS
	I.3	DIMENSIONAL INSPECTION	LOT SAMPLING, AQL 2.5%
III	NA	MECHANICAL INSPECTIONS	CATEGORY TITLE
	III.A	OPTICAL/MECHANICAL INSPECTIONS	CATEGORY TITLE
	III.A.1	WAVEFRONT DISTORTION INSPECTION	ALL UNITS
	III.A.2	REFLECTED BEAM DEVIATION INSPECTION	LOT SAMPLING, AQL 2.5%
	III.A.3	TRANSMITTED BEAM DEVIATION INSPECTION	ALL UNITS
	III.B	FUNCTIONAL INSPECTIONS/TESTS	CATEGORY TITLE
	III.B.1	ANTIREFLECTION COATING TESTS	WITNESS SAMPLE
	III.B.2	POLARIZATION COATING TESTS	ALL UNITS
IV	NA	ENVIRONMENTAL TESTS	CATEGORY TITLE
	IV.1	POLARIZATION COATING TEMPERATURE TEST	1 PER LOT
	IV.2	POLARIZER HUMIDITY TEST (FOR VENDOR QUALIFICATION ONLY)	1 PER LOT
	NA	RELIABILITY TEST	CATEGORY TITLE
	VI.1	DAMAGE TEST (FOR VENDOR QUALIFICATION ONLY)	1 PER LOT

2.0 INSPECTION/TEST SUMMARY

2.1 Test Summary

Figure 2.1, Inspection/Test Summary consolidate the results of this evaluation.

2.2 Conclusion

34 out of 50 polarizers were accepted for all tested specifications. 13 out of 50 were rejected due to insufficient clear apertures(1), two (2) for incomplete bond lines, and one (1) for p-polarization transmission. These are not technical or design problems, but rather Quality Control problems of which responsible personnel at Airtron have been notified.

(1) Clear apertures were increased in Phase III over Phase II requirements. The smaller clear apertures were the result of utilizing Phase II coating tooling in error.

Procedure	Title	Accepted	Rejected
I	Visual Mechanical Inspections	35	15
I.1	Surface Quality Inspection	50	0
I.1.1	Scratch & Dig Inspection Procedure	50	0
I.1.2	Chip Inspection	50	0
I.1.3	Coating & Cosmetic Blemish Inspection	50	0
I.2	Internal Defects Inspection	35	15
I.3	Dimensional Inspection	50	0
III	Mechanical Inspections	50	0
III.A	Optical/Mechanical Inspections	50	0
III.A.1	Waveform Distortion Inspection	50	0
III.A.2	Reflected Beam Deviation Inspection	50	0
III.A.3	Transmitted Beam Deviation Inspection	50	0
III.B	Function Inspection/Tests	49	1
III.B.1	Antireflection Coating Tests	50	0
III.B.2	Polarization Coating Tests	49	1
IV	Environmental Tests	50	0
IV.1	Polarization Coating Temperature Test	50	0
IV.2	Polarizer Humidity Test	50	0
VI	Reliability Test	50	0
VI.1	Damage Test	50	0

HRLP Lot Number EG9U0617-A

Number: ______ Number: ______

Accepted: 34 Rejected: 16

Comments: Rejected S/N's: 114, 125, 143, 145, 151, 152, 156, 172, 188, 192, 196, 200, 207, 217, 219, 239.

Figure 2.1 Inspection/Test Summary Sheet

3.0 FACTUAL DATA

3.1 Test Apparatus

Unless otherwise stated, the test apparatus used in this evaluation conform to those called out in the respective procedures in the Evaluation Plan, CDRL D001.

3.2 Test Procedures

Unless otherwise stated, the test procedures used in this evaluation follow closely the respective procedure in the Evaluation Plan, CDRL D001.

3.3 Test Data and Results

Data for performance specification, i.e. contrast ratio, P-polarization transmission and laser damage are reported at measured values for other specifications, data are reported as pass or fail, with a measured value accompanying the failing status.

Raw data and results of this evaluation are maintained in LLS Optical Inspection for one year, under a file heading, HRLP, Phase II, Data.

3.3.1 Visual Mechanical Inspection

The High Reliability Laser Polarizers were first subjected to visual mechanical inspection. All 50 polarizers passed scratch-dig, coating and cosmetic and dimensional inspections. 16 out of 50 failed internal defects inspection. Table 3.3.1, Visual Mechanical Inspection Data & Results consolidates the results of this inspection.

Data sheets for the failed specification are included in Appendix A.

3.3.2 Mechanical Inspection

The polarizers were then subjected to inspection for wavefront distortion, reflect and transmitted beam deviations. All 50 polarizers passed these inspections. Table 3.3.2A, Optical/Mechanical Inspection summarizes the results.

Anti-reflection coating witness samples were tested next. Figures 3.3.2 A & B illustrates the results of this inspection. The two witness samples met required specifications.

Polarization coating test was performed on all 50 polarizers. Upon receipt of 50 HRLP's, it was noticed that interference fringes were present at the air gap interfaces on many polarizers. This prompted the measurement of P-polarization transmission first and those which failed this test were immediately returned to Airtron for re-assembly. Table 3.3.2B presents data taken after re-assembly of the HRLP's.

Specification for P-polarization transmission is $\%T_p \geq 98$. To our experience, measurement errors resulting from alignment tolerance, beam displacement due to transmitted beam deviation and rounding up of ratiometer's display digits could considerably vary measurement results. For this reason, a 1% measurement error was allowed and polarizers with $\%T_p \geq 97\%$ were considered acceptable.

3.3.3 Environmental Test

One HRLP sample, S/N 112 was selected for polarization coating temperature test. In this test, contrast ratio $\frac{T_p}{T_s}$ and P-polarization transmission $\%T_p$ at 0°, -.5° and -1° incidences were monitored at room temperature 70°C and -40°C. Table 3.3.3A presents the results of this test.

Another HRLP sample, S/N 464 was selected for humidity test at 98% relative humidity, for 24 hours at 110°F. Contrast ratio and P-polarization transmissivity were measured both before and after this test. The results are listed in Table 3.3.3B.

3.3.4 Reliability Test - Laser Induced Damage Threshold Test

One sample, S/N 133, was sent to Montana Laser Optics for laser induced damage threshold test. The test procedure is described in details in Appendix B and is comparable to the procedure described in CDRL D001, Secstion VI.1. Table 3.3.4 presents the results of this test.

Since the stated damage threshold in the Montana Laser Optics report is the power density at the polarization coating interface, this number must be adjusted by a factor of $1/_{\cos\theta}$ to arrive at the input power density, or

$$\text{Input Power Density} = \frac{\text{INTERFACE POWER DENSITY}}{\cos\theta}$$

Where θ is the angle between the entrance surface and the polarization coating interface of the HRLP and is equal to 40° 40'.

TABLE 3.3.1 VISUAL MECHANICAL INSPECTION

INSPECTION	SPECIFICATION	# ACCEPTED	# REJECTED
Scratch & Dig	20-10	50	0
Coating Cosmetic	Refer to CDRL D001	50	0
Dimensional	Refer to CDRL D001	50	0
Internal Defects	Refer to CDRL D001	35	15

TABLE 3.3.2A OPTICAL/MECHANICAL INSPECTION

INSPECTION	SPECIFICATION	# ACCEPTED	# REJECTED
Wavefront Distortion	$\leq \frac{\lambda}{4}$	50	0
Reflected Beam Deviation	$\leq$ 4 arc min	50	0
Transmitted Beam Deviation	$\leq$ 2 arc min	50	0

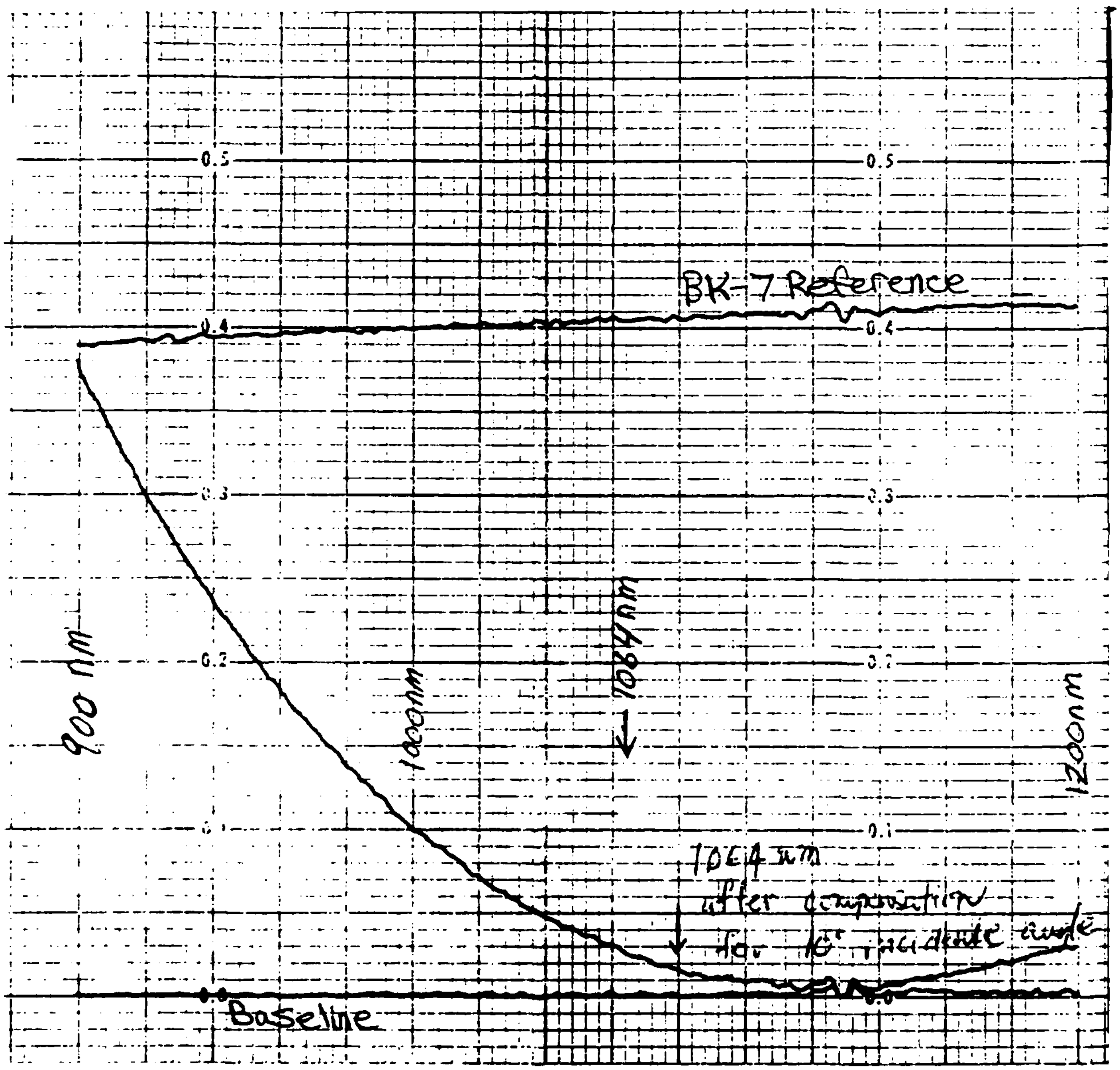

Figure 3.3.2A Antireflection Coating Scan Response Plot
Surfaces A & C

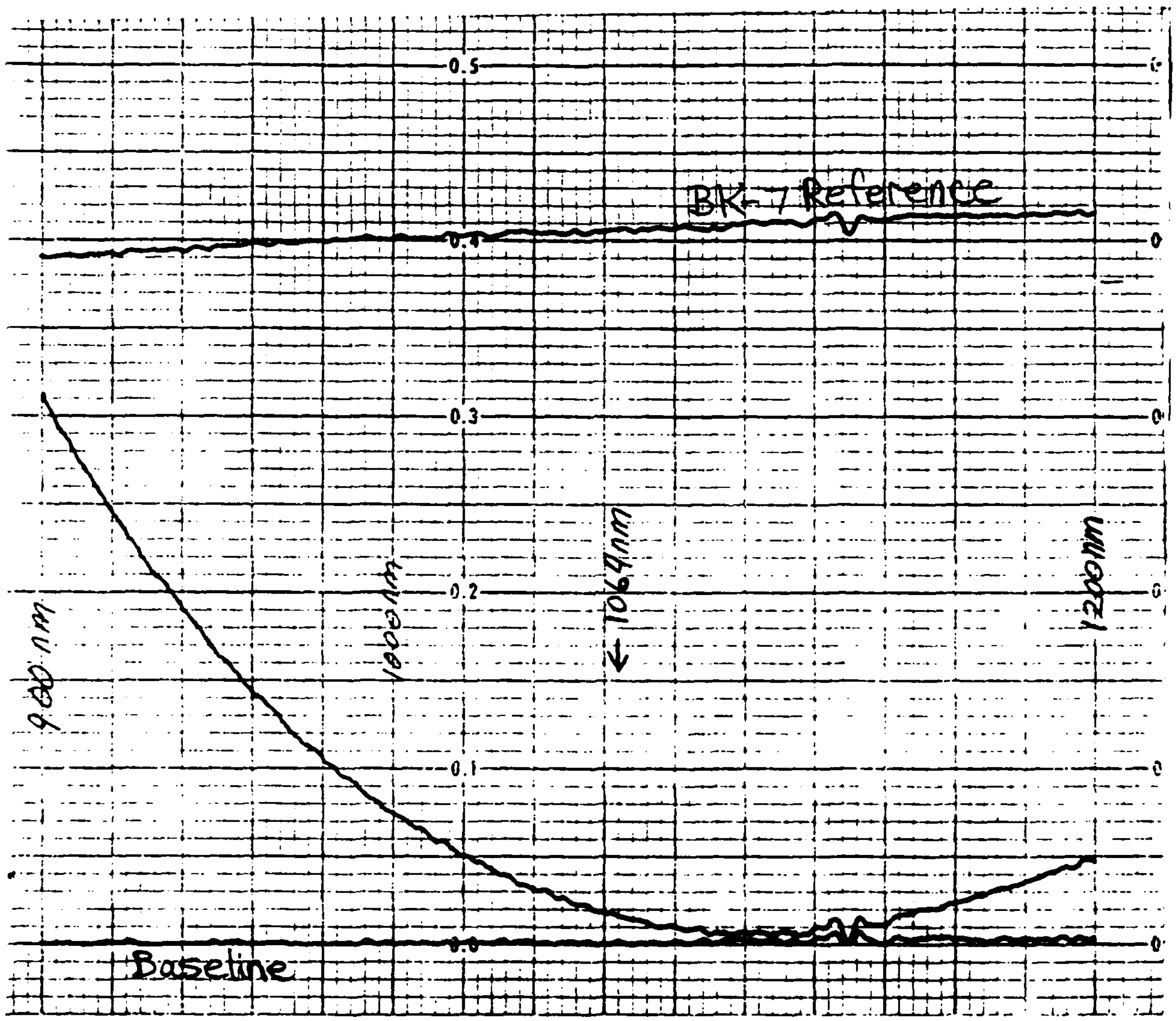

Figure 3.3.2B Antireflection Coating Scan Response Plot
Surfaces B & D

TABLE 3.3.2B POLARIZATION COATING TEST RESULTS

S/N	INC. ANGLE = 0°		INC. ANGLE = -.5°		INC. ANGLE = -1.0°		ACCEPT/ REJECT
	$\%T_p$	C.R.	$\%T_p$	C.R.	$\%T_p$	C.R.	
112	98.3	952	99.0	1123	97.7	1250	Accept
114	99.0	735	99.3	793	99.7	847	Accept
125	98.0	1111	99.0	1219	99.7	1351	Accept
127	99.7	1063	99.0	1219	99.3	1351	Accept
133	98.3	1008	99.0	1128	99.3	1249	Accept
134	99.0	961	99.3	1042	99.0	1136	Accept
136	99.0	909	99.0	961	99.7	1089	Accept
140	98.0	926	98.6	1020	99.0	1136	Accept
143	99.7	820	98.6	909	99.3	1020	Accept
145	99.0	909	99.0	1042	99.3	1162	Accept
151	98.6	769	99.0	862	98.0	961	Accept
152	99.7	781	98.6	862	98.6	961	Accept
156	98.6	649	98.6	704	99.0	769	Accept
171	98.0	781	98.6	862	99.3	926	Accept
172	98.3	781	98.3	862	99.3	961	Accept
179	99.3	806	99.7	877	98.6	961	Accept
180	99.0	980	99.0	1111	99.3	1282	Accept
188	98.7	1020	98.7	1219	96.7	1351	Reject
189	98.7	1089	98.7	1282	97.7	1428	Accept
190	99.7	1250	99.7	1428	99.0	1562	Accept
192	99.3	1250	99.3	1470	98.3	1667	Accept
194	99.0	1282	98.7	1515	97.3	1724	Accept
196	99.7	1250	99.3	1470	98.3	1667	Accept
198	100.	1219	99.3	1389	97.4	1613	Accept
200	100.	1250	99.0	1428	97.0	1613	Accept
202	97.7	1282	98.7	1470	97.3	1667	Accept
204	99.3	1351	99.0	1562	97.4	1786	Accept
207	100.	1282	99.3	1515	98.7	1724	Accept
217	99.7	1250	99.3	1428	98.3	1613	Accept
219	99.3	1219	99.3	1351	98.3	1515	Accept
220	98.6	1351	98.0	1613	97.3	1852	Accept
223	99.3	1428	98.7	1667	97.7	1923	Accept
226	99.3	1219	99.0	1351	98.3	1562	Accept
228	99.7	1162	99.3	1315	99.0	1515	Accept
229	99.7	1162	99.3	1315	98.3	1470	Accept
232	99.7	1351	99.0	1613	98.0	1852	Accept
234	100.	1428	99.3	1667	97.0	1923	Accept
236	99.7	1111	99.3	1250	98.0	1470	Accept
239	99.7	1136	99.3	1282	98.3	1470	Accept
240	99.6	1786	99.0	2174	98.0	2500	Accept
245	99.7	1219	99.7	1389	98.3	1562	Accept
247	100.	1282	99.0	1470	97.7	1724	Accept

TABLE 3.3.2B POLARIZATION COATING TEST RESULTS (CONT'D)

S/N	INC. ANGLE = 0°		INC. ANGLE = -.5°		INC. ANGLE = -1.0°		ACCEPT/ REJECT
	$\%T_p$	C.R.	$\%T_p$	C.R.	$\%T_p$	C.R.	
330	98.0	1219	99.1	1357	99.7	1613	Accept
452	97.7	1717	97.7	1940	97.2	2251	Accept
457	98.7	2410	98.4	2770	98.6	3271	Accept
458	99.0	1502	98.8	1702	97.9	1942	Accept
460	99.0	1494	98.0	1735	97.2	1992	Accept
464	99.5	800	99.2	800	98.0	800	Accept
467	99.0	1553	99.0	1810	98.0	2188	Accept
468	99.0	1454	98.7	1671	98.0	1934	Accept

TABLE 3.3.3A POLARIZATION COATING TEMPERATURE TEST RESULTS HRLP #112

TEMPERATURE	INC. ANGLE = 0°		INC. ANGLE = -.5°		INC. ANGLE = -1.0°		ACCEPT/ REJECT
	$\%T_p$	C.R.	$\%T_p$	C.R.	$\%T_p$	C.R.	
73°F (22°C)	98.3	952:1	99.0	1123:1	98.7	1250:1	Accept
158°F (70°C)	99.0	1111:1	98.7	1250:1	98.7	1613:1	Accept
-40°F (-40°C)	98.6	980:1	98.6	1220:1	98.0	1389:1	Accept

TABLE 3.3.3B $\%T_p$ AND CONTRAST RATIO BEFORE AND AFTER HUMIDITY TEST - HRLP #464

SPECIFICATION: $\% T_p \geq 98\%$, $CR \geq 300:1$							
	INC. ANGLE = 0°		INC. ANGLE = -.5°		INC. ANGLE = -1.0°		ACCEPT/ REJECT
	$\%T_p$	C.R.	$\%T_p$	C.R.	$\%T_p$	C.R.	
Before Humidity Test	99.5	800[1]	99.2	800[1]	98.0	800[1]	Accept
After Humidity Test	100	1587	98.1	1876	97.2	2212	Accept

[1] At time of measurement of Contrast Ratio before the humidity test, test equipment malfunctioning necessitates the use of a different detector. The resolution of the new detector only permit readings of up to 800 for contrast ratio. Actual contrast ratios are higher than 800:1, as evident in the after humidity test data.

TABLE 3.3.4 DAMAGE THRESHOLD TEST RESULTS HRLP #133

POLARIZATION	SPECIFICATION	DAMAGE THRESHOLD	ACCEPT/ REJECT
S	500 MW/cm^2	646 MW/cm^2	ACCEPT
P	500 MW/cm^2	501 MW/cm^2	ACCEPT

APPENDIX A

DATA SHEETS FOR FAILED SPECIFICATIONS

Data Sheets for failed specifications are included here to provide more information on the extent of the failures.

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 192

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:_____ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:_____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:_____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes: ✓ No:_____

AVAILABLE CA : .350

5. The HRLP is:

Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 217

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:____ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes: ✓ No:____
AVAILABLE CA : .340

5. The HRLP is:

Accepted:______ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:_______________ HRLP SERIAL NUMBER: 207

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:_______ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:_______ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:_____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes: ✓ No:_____

AVAILABLE CA: .350"

5. The HRLP is:

Accepted:___________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________ HRLP SERIAL NUMBER: 239

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:____ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes: ✓ No:____

AVAILABLE CA : .360"

5. The HRLP is:

Accepted:______ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 219

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:_____ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:_____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

<u>Acceptance Criteria:</u> No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:_____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes: ✓ No:_____

AVAILABLE CA: .360"

5. The HRLP is:

Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________ HRLP SERIAL NUMBER: 172

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:____
   AVAILABLE CA: .320"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

   Accepted:______ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________________ HRLP SERIAL NUMBER: 156

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:______
   AVAILABLE CA : .320

2. Were any stria observed per paragraph I.2.4.3.2? Yes:______ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:______

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:______ No: ✓

5. The HRLP is:

Accepted:____________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________ HRLP SERIAL NUMBER: 152

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:____
   AVAILABLE CA : .320"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

<u>Acceptance Criteria:</u> No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

   Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 151

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:_____
   AVAILABLE CA: .330"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:_____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:_____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:_____ No: ✓

5. The HRLP is:

   Accepted:__________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 145

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:____
AVALABLE CA: .320"

2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
O	O	O

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

<u>Acceptance Criteria:</u> No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

Accepted:__________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________ HRLP SERIAL NUMBER: 114

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:____
   AVAILABLE CA : .320"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

   Accepted:______ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 143

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:_____
   AVAILABLE CA : .315"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:_____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:_____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:_____ No: ✓

5. The HRLP is:

   Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:__________ HRLP SERIAL NUMBER: 125

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes: ✓ No:____
   AVAILABLE CA: .290"
2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓
3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes: ✓ No:____

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________ HRLP SERIAL NUMBER: 196

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:____ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:____ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

Acceptance Criteria: No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes:____ No: ✓
cleaning Solvent Sips into air gap.

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:____ No: ✓

5. The HRLP is:

Accepted:________ Rejected: ✓

FIGURE I.2.4.4-1 INTERNAL DEFECTS DATA SHEET

INSPECTION DATE:________________ HRLP SERIAL NUMBER: 200

1. Does air-gap separation pad(s) extend into CA per paragraph I.2.4.3.1? Yes:________ No: ✓

2. Were any stria observed per paragraph I.2.4.3.2? Yes:________ No: ✓

3. Record the "Dig Number" corresponding to any bubble or inclusion per paragraph I.2.4.2.4, below:

DIG NUMBER	BUBBLE (✓)	INCLUSION (✓)
0	0	0

NOTE: If more than three (3) bubbles and inclusions exist in the HRLP, record the three (3) largest.

<u>Acceptance Criteria:</u> No HRLP shall contain more than one (1) Number 10 dig or more than two (2) Number 5 digs. See paragraph I.2.4.3.4.a.

4.a. Does the bond line form an air-tight seal around the perimeter interface per paragraph I.2.4.3.4.a. Yes:_____ No: ✓

cleaning solvent sips into air gap.

4.b. Does any adhesive material extend into the CA per paragraph I.2.4.3.4.b. Yes:_____ No: ✓

5. The HRLP is:

Accepted:__________ Rejected: ✓

APPENDIX B

LASER DAMAGE TEST REPORT AND TEST DESCRIPTIONS

The damage test procedure used by Montana Laser Optics is consistent with the procedure soecified in CDRL D001, Section VI.1, it is included here to assure the integrity of the damage test results. As indicated in 3.3.4 the power density must be adjusted by the factor $\left(\frac{1}{\text{coo } 40° \; 40'}\right)$ thus:

S-polarization Damage Threshold $= \dfrac{490 \text{ MW/}_{\text{cm}^2}}{\text{coo } 40° \; 40'} = 646 \text{ MW/}_{\text{cm}^2}$

P-polarization Damage Threshold $= \dfrac{380 \text{ MW/}_{\text{cm}^2}}{\text{coo } 40° \; 40'} = 501 \text{ MW/}_{\text{cm}^2}$

MONTANA LASER OPTICS*,INC.

6 October 1987

Mr. Larry Jones
Litton Laser Systems
2787 S. Orange Blossom Trail
Apopka FL, 32703

SUBJECT: DAMAGE THRESHOLDS FOR POLARIZER CUBE 133

Dear Larry:

This letter reports laser exposure testing of one assembled polarizer cube, per your purchase order no 100316. General descriptions of the test facility and exposure procedure are provided in the enclosed boilerplate document "Damage Test Descriptions". The specific experimental parameters used are detailed on the enclosed Laser Exposure Test Summary sheets. The measured laser damage thresholds are tabulated below. Here "damage" refers to any laser-induced change to the polarizing surface, and "threshold" refers to the least intensity which caused damage. Measurement precision was $\pm$ 10%.

Table 1. Polarizer cube hypotenuse

Sample	Polariz.	Fluence (J/cm^2)	Intensity (MW/cm^2)
133	S	12.	490
	P	9.6	380

As in previous cube polarizer tests, the sample was exposed through the entrance face at normal incidence. The numbers in table 1 refer to the inclined plane of the polarizer coating. The spatial profile was analyzed in the plane of the entrance face. To obtain the spot area at the internal polarizing surface, it was necessary to correct for spot size changes due to incidence angle and divergence of the beam as it passed through the sample.

Damage assessment was made with a low-power hand magnifier and strong white-light illumination as before. The smallest damage which could be seen on the internal surface was a small pit.

P.O. BOX 4151, BOZEMAN, MT 59772-4151 (406) 586-5100

*Optics Testing, Instrumentation and Consulting Services

Sincerely yours,
MONTANA LASER OPTICS*, INC.

Mark T. Babb

Mark T. Babb
Laser Exposure Testing Engineer

Encl: (1) DTD August 1985
(2) LETS 6 Oct 87 #1-2

Copy: S.C. Seitel SCS

MONTANA LASER OPTICS*, INC.

LASER EXPOSURE TEST SUMMARY

Run ID: 6-Oct-87 # 1

Customer: Litton Laser Systems

Purchase order: 100316

Sample ID: 133

Release no.:

Substrate: (Assembled cube)

Coating: Polarizing @ 1064 nm

Preparation: Acetone/methanol drag wipe

Pre-exposure inspection: Hand lens

Test type: Threshold

Test parameters:

Wavelength (nm): 1064

Incidence angle (deg.): 0

Repetition rate (Hz): 10.7

Polarization: P-state

Pulse width (FWHM, ns): 20

Spot size (FW1/e2, mm): .98

Axial modes: SPO

Transverse modes: TEMoo

No. of sites: 11

No. shots/site: 100

Damage definition: Permanent surface change

Post-exposure inspection: Hand lens

Test result: Threshold 9.6 J/cm2 (~ 380 MW/cm2). Spread 0.00

Comments:
Threshold damage was a small pit.

Mark T. Babb

Date: 10/06/87

P.O. BOX 4151, BOZEMAN, MT 59772-4151 (406) 586-5100

MONTANA LASER OPTICS*, INC.

LASER EXPOSURE TEST SUMMARY

Run ID: 6-Oct-87 # 2

Customer: Litton Laser Systems

Purchase order: 100316

Sample ID: 133

Release no.:

Substrate: (Assembled cube)

Coating: Polarizing @ 1064 nm

Preparation: Acetone/methanol drag wipe

Pre-exposure inspection: Hand lens

Test type: Threshold

Test parameters:

Wavelength (nm): 1064	Incidence angle (deg.): 0
Repetition rate (Hz): 10.7	Polarization: S-state
Pulse width (FWHM, ns): 20	Spot size (FW1/e2, mm): .98
Axial modes: SPO	Transverse modes: TEMoo
No. of sites: 21	No. shots/site: 100

Damage definition: Permanent surface change

Post-exposure inspection: Hand lens

Test result: Threshold 12.2 J/cm2 (~ 490 MW/cm2). Spread 0.00

Comments:
Threshold damage was a small pit.

Mark T. Babb

Date: 10/06/87

P.O. BOX 4151, BOZEMAN, MT 59772-4151 (406) 586-5100

*Optics Testing, Instrumentation and Consulting Services

MONTANA LASER OPTICS*, INC.

DAMAGE TEST DESCRIPTIONS

August 1985

INTRODUCTION

Montana Laser Optics*, Inc. provides a full range of laser-damage test services to laser systems manufacturers and their optics suppliers. This document provides a general description of the test apparatus, calibration, sample handling, test procedures, and documentation employed in laser exposure testing of customer-supplied optical samples.

EXPERIMENTAL ARRANGEMENT

The experimental arrangement is shown in Fig. 1, and pertinent parameters are summarized in Table 1. The test source is a flashlamp-pumped, electro-optically Q-switched, frequency-doubled Nd:YAG oscillator-amplifier system constrained to operate in a single transverse mode (TEM_{00}) by an intracavity aperture. For multimode tests, this aperture is removed. An intracavity etalon restricts the number of longitudinal modes which oscillate, resulting in a single-lobed temporal waveform with approximately 5% high frequency amplitude modulation superimposed. The etalon is removed to obtain the standard multiple-lobed temporal waveform characteristic of Q-switched Nd:YAG lasers. Pulse duration is set to the required value by altering the Q-switch timing, the length of the optical resonator, or both.

The output of the test source (Nd:YAG) is set to the desired intensity with a variable attenuator (A), combined at a dichroic (D) with the visible beam from a low-power helium-neon laser (He-Ne), and delivered to the test sample (S) located at or near the focus of a converging lens (L). Use of a lens permits generating destructive intensities at the test sample. The lens is mounted on a translation carriage which allows setting the irradiated spot size to the desired value; once set, spot size is held constant during the test. The sample is mounted in a precision multi-axis manipulator which is used to position different test sites in the beam, and to set the incidence angle. The polarization state is set with a waveplate (W) or depolarizer. The incident laser pulse is sampled with an uncoated quartz wedge (Q); portions of the beam are directed to a diagnostics package (P) which permits simultaneous determination of the total pulse energy, peak axial intensity, and spatial and temporal waveforms. The sample surface and the visible laser radiation scattered from it are observed with a 20X optical microscope (M).

P.O. BOX 4151, BOZEMAN, MT 59772-4151 (406) 586-5100

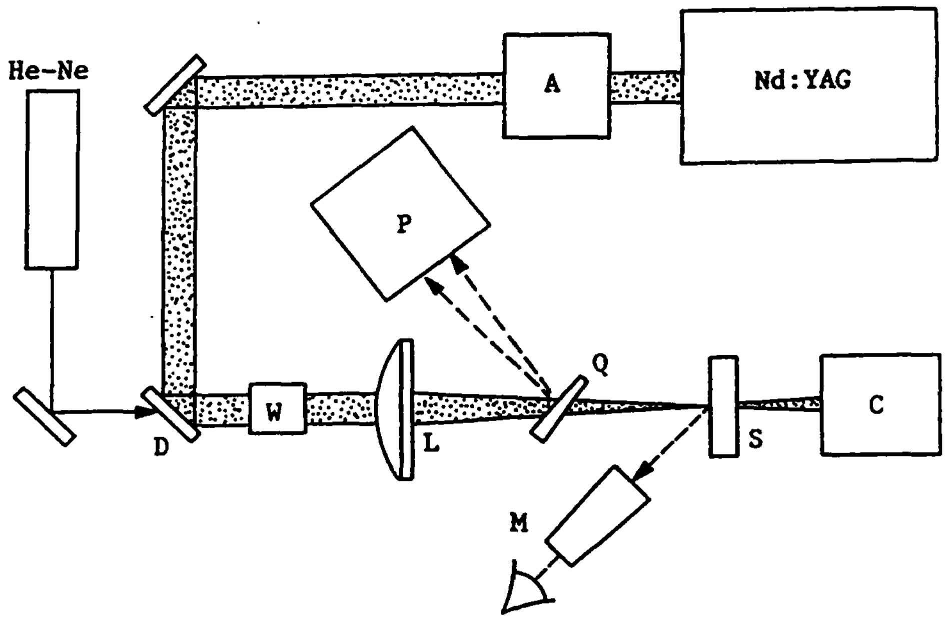

Figure 1. Experimental Arrangement. See text for description.

Table 1. Damage Test Station Specifications

Wavelength:	1064 nm or	532 nm
Pulse energy:	500 mJ, max	150 mJ, max
Repetition rate:	Up to 20 Hz, in discrete steps	
Temporal profile:	"Smooth pulse" or multimode	
Pulse duration:	8-30 ns, FWHM	
Spatial profile:	TEM_{00} or multimode	
Spot size:	Up to 8 mm, $FW1/e^2$	
Incidence angle:	Normal to grazing	
Polarization state:	Linear, circular, depolarized	

LASER PULSE CHARACTERIZATION

Damage test results usually are reported in terms of maximum pulse intensities (W/cm^2) or fluences (J/cm^2). The parameter routinely measured in a damage test, however, is the total pulse energy (J), since this may be done simply and accurately with a commercial calorimeter. Evaluation of the distribution of this energy in space (the spatial profile) and time (the temporal profile) is more complex, and is performed only periodically. Rigorous relationships between pulse energy, fluence, power, and energy follow from in' gration of the pulse profiles.

Absolute single-point calibration of the pulse monitoring system is performed by removing the sample and allowing the laser pulse to enter a calibrated volume-absorbing calorimeter (C) directly. The calorimeter is a commercial device, with manufacturer's stated accuracy of 3%, NBS traceable. Periodic calibration verification is performed by electrical substitution heating of the thermopile and by direct comparison with a second calorimeter.

The temporal profile is observed with a fast silicon photodiode and calibrated 300 MHz oscilloscope. A typical digitized pulse is shown in Fig. 2. The general form is nearly Gaussian, but with an extended tail which contains a non-negligible fraction of the pulse energy. Numerical integration of this waveform to yield the ratio of peak power to total pulse energy is straightforward. The photodiode is also used to monitor any shot-to-shot variation in the temporal profile. Variation of the peak power to total energy ratio typically is less than 5%.

Periodically, a complete two-dimensional analysis of the spatial profile is performed with an advanced intensity profiling system based on a silicon array camera and video frame grabber. The camera array is located precisely in the target plane or equivalent, and its sweep is synchronized to the laser by means of a flashlamp radiation sensor. Data acquired by the frame grabber is transferred to a computer for near real-time analysis of individual laser pulses. A commercial software package[1] permits quantitative determination of pulse energy and maximum fluence, and provides graphics displays of the spatial profile in several formats (Fig. 3). Independent verification of the distribution of radiation in the target plane is obtained by scanning the focal region with a pinhole and silicon photodiode. A typical scan is plotted in Fig. 4, where each data point represents the average of approximately 20 individual pulses. With both methods, the distribution is nearly Gaussian in form, as indicated by the least-squares best-fit curves. Numerical integration of either profile yields the ratio of maximum fluence to total pulse energy in the target plane. Any shot-to-shot variation is monitored in real time with a 1024 element silicon diode array with sweep synchronized to the laser pulse rate. Variation of the maximum fluence to total energy ratio typically is less than 5%.

---

[1] BEAMCODE 2.0, Big Sky Software Corp., Bozeman, Montana

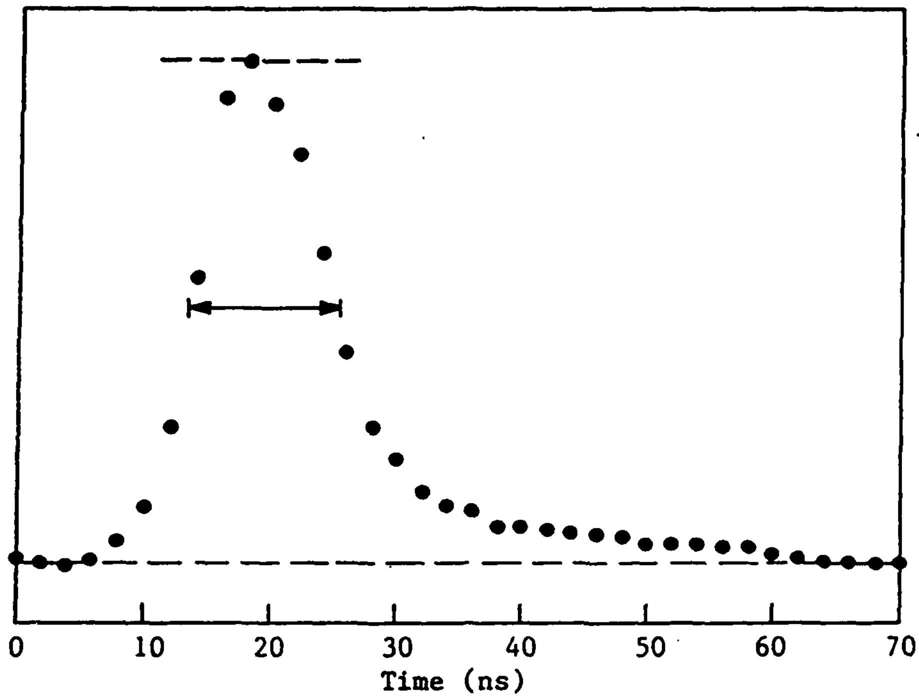

Figure 2. Temporal Profile. Pulse duration is 12 ns FWHM.

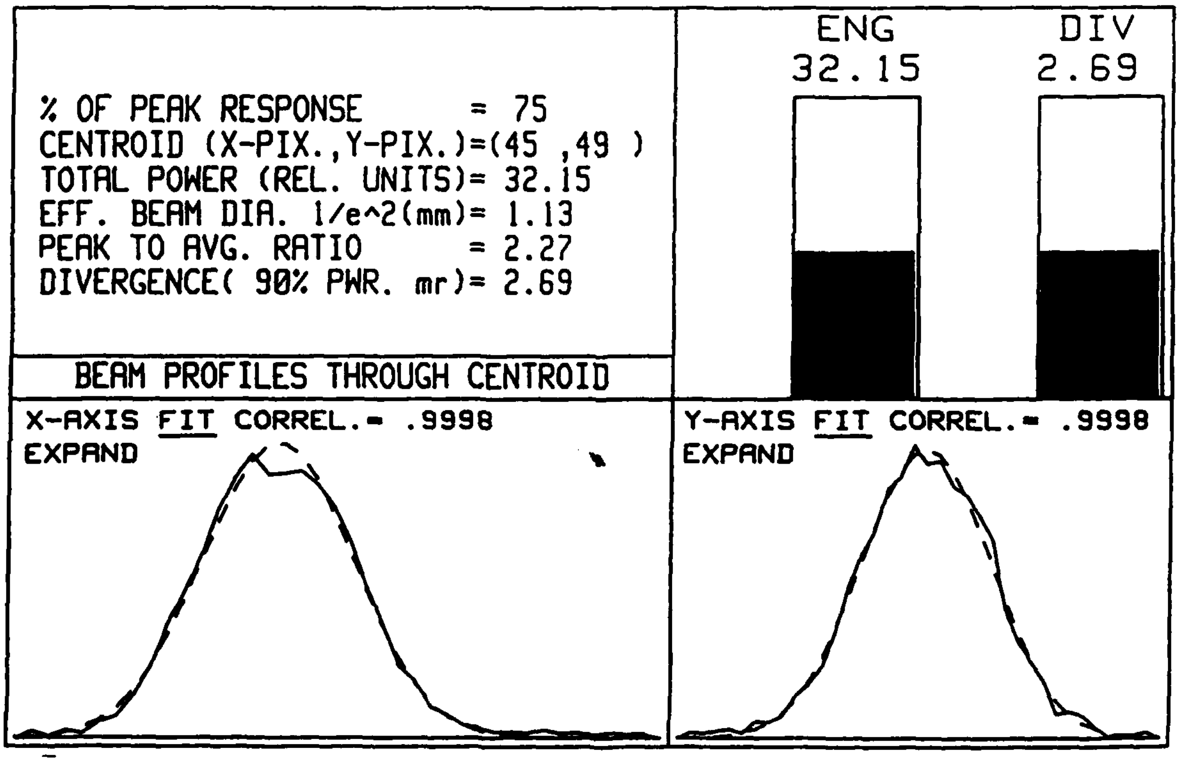

Figure 3. Spatial Profiles Obtained with Array Camera. Spot size is 1.13 mm FW1/e^2.

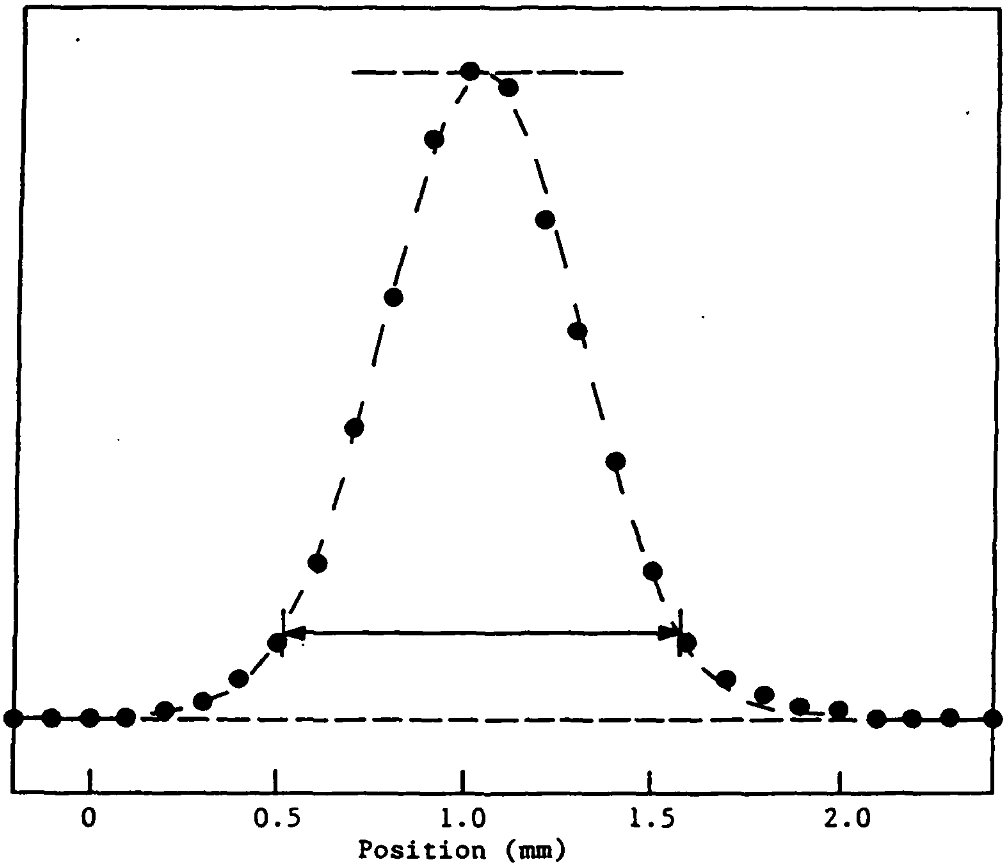

Figure 4. Spatial Profile Obtained by Scanning Beam with Pinhole. Spot size is 1.05 mm FW1/e^2.

TEST SAMPLES

The damage test station is equipped with a variety of interchangeable holders to permit mounting test samples of different sizes and shapes. Most frequently tested are coated glass witness pieces; typically these measure 1-2 in. in diameter, with thickness of 1/16-1/4 in. One flat surface (the test surface) has been carefully polished and coated, while the reverse generally is uncoated and has only a commercial "window" polish. Deliverable parts with more complex geometries are tested if witness samples are not available. Pieces of unusual size or shape occasionally require fabrication of specialized holders.

After an initial inspection, samples are stored in a dessicating cabinet. Before testing, any loose particulates are removed by applying a low-pressure stream of nitrogen gas, followed by drawing a lens tissue saturated with methanol or other high purity solvent across the test surface. More vigorous cleaning procedures are not attempted unless required by the customer. A microscopic evaluation of surface quality and cleanliness is performed. After testing, samples are returned to the customer or archived for possible additional testing.

DAMAGE TEST PROCEDURES

1. Damage threshold determination. "Damage" is defined as any laser-induced change which is observable at high magnification with a differential interference contrast or darkfield microscope. "Threshold" is defined to be the least intensity (or fluence) sufficient to induce damage at any test site. The maximum safe operating intensity is not greater than this value. To determine the damage threshold, a number of separate sites on the sample are irradiated, each at a different intensity. The intensities used are distributed approximately uniformly over a range including the anticipated failure level. Each site is observed immediately before, during, and after irradiation with the on-line 20X microscope, and any visible change, plasma formation, or change in the scatter of the He-Ne laser beam is noted. After exposure, the test sites are examined microscopically to identify and characterize laser-induced changes. Color photomicrography in several formats is available as needed.

Typical damage threshold data, in this case for pitting of an AR-coated BK-7 glass sample, are plotted in Fig. 5. Below about 720 MW/cm^2 ("threshold"), no damage occurred. Above 780 MW/cm^2, all sites tested failed. The transition from no damage to damage ("spread") is not a step function because the coating was spatially non-uniform on a scale larger than the irradiated spot size (~500 um). For most bulk materials, and for many bare polished surfaces and coatings, the width of this transition region is very narrow. The threshold is well defined, and may be extracted from data on as few as 10 sites.

On some surfaces, even when tested with large spot diameters, the spread may be quite large, and many sites must be exposed to ensure that the weak areas are found. In this event, an alternate procedure permits more systematic extraction of the damage threshold. Several sites (typically 10) are exposed at one intensity, and the percentage of these which damage is noted. The intensity is then reduced, and more sites are exposed. This procedure is repeated to develop a plot of damage percentage vs. intensity. An example for uncoated lithium niobate is shown in Fig. 6. Extrapolation to zero damage percentage yields the threshold, in this case about 300 MW/cm^2. Rigorous data acquisition and extrapolation methods exist, but in practice a linear fit often is sufficient.

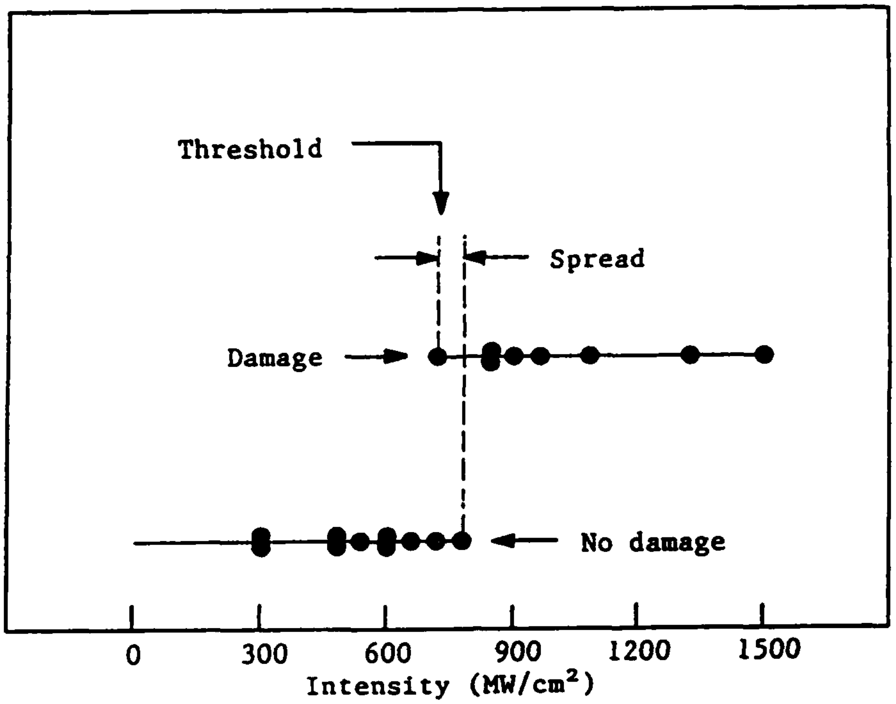

Figure 5. Threshold Plot for Antireflection-Coated BK-7 Glass. Data were obtained with the primary test procedure (see text).

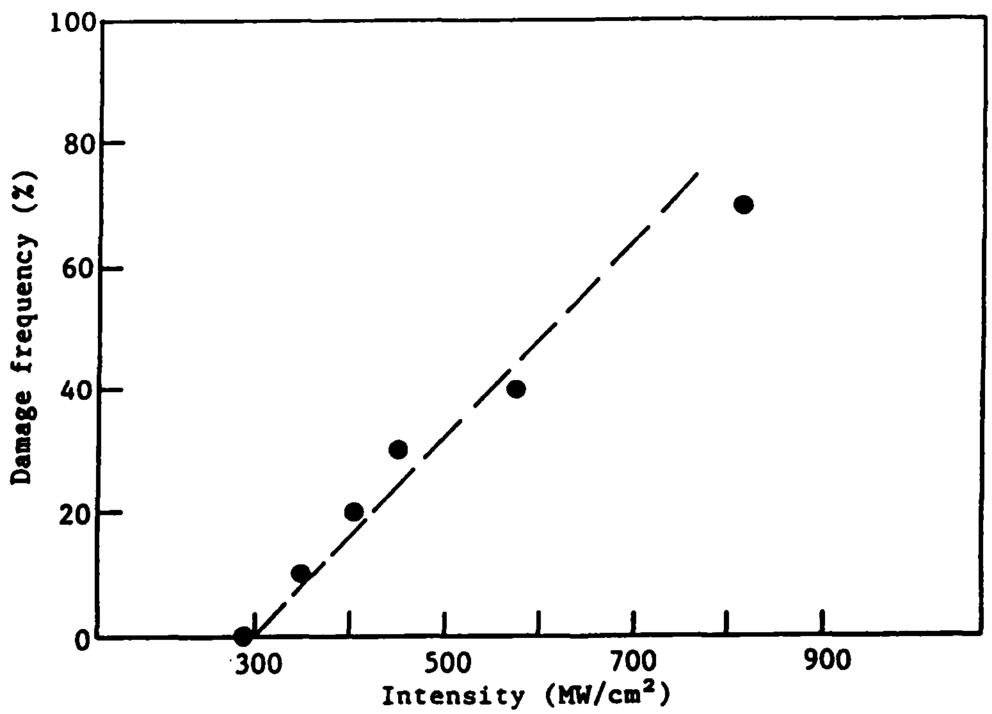

Figure 6. Threshold Plot for Uncoated Lithium Niobate. Data were obtained with the alternate test procedure (see text).

2. Optical durability certification. This simpler test is used to verify optical durability to a drawing or other procurement specification. Several randomly selected sites (typically six) are exposed to laser radiation at one specified combination of intensity, repetition rate, pulse duration, spot size, etc. The sample is observed as before with the on-line 20X microscope, and a detailed microscopic damage assessment is performed after exposure. Damage at any site constitutes "failure" in this test.

3. Lifetime testing. This extended version of the certification test is useful when durability must be demonstrated over an extended operating period. The sample is exposed for the specified length of time or number of pulses. Photomicrographs of the test site before and after exposure are compared to identify and characterize changes.

4. Custom testing. Specialized laser damage tests are performed to unique customer requirements. Test procedures are developed on a case-by-case basis.

DOCUMENTATION

Each sample is assigned a unique run number and multi-part Laser Exposure Test Control form which accompanies it though the test process from inital receipt to submission of the final report. All pertinent facts pertaining to test station configuration, source calibration, cleaning, microscopic inspections, exposure parameters, raw data, and reduced test results are recorded on this form, which is retained for permanent reference. This enables precise duplication of test conditions when testing similar samples.

A Summary Test Report is standard. Prepared in letter format, it documents exposure conditions, test results, and principal conclusions, and is submitted immediately after testing is completed. An optional Extended Test Report includes, in addition, detailed descriptions of test procedures, laser source characterization, and photomicrographs of typical damage sites. It is intended as a stand-alone, publication-quality report of measurements made on customer-supplied optical samples.

Report DAAK20-85-C-0137

MANUFACTURING METHODS & TECHNOLOGY
FINAL REPORT

Chuck Stonecypher, 297-4458
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29 January 1988

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes the development of a domestic (USA) source of high energy laser polarizers. The polarizers were specifically cube polarizers designed for 1.064 μm radiation from Nd:YAG lasers. The domestic source completed a production readiness review culminating in a production lot sample of 50 polarizers. The polarizers were inspected using a government approved quality plan and were found in general to satisfy all technical requirements.

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MANUFACTURING METHODS AND TECHNOLOGY

FINAL REPORT, PHASE III

REPORT NO. DAAK20-85-C-0137

01 MARCH 1987 - 29 JANUARY 1988

OBJECT OF STUDY

THE OBJECT OF THIS STUDY WAS THE DEVELOPMENT AND TRANSFER OF TECHNOLOGY FOR PRODUCTION OF HIGH ENERGY LASER POLARIZERS TO TWO DOMESTIC (USA) SUPPLIERS.

MIL-STD-847A APPLIES TO THIS REPORT

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DISTRIBUTION TBD

SUMMARY

Phase III contract development work continued towards the production of high energy laser polarizers for Nd:YAG lasers. The subcontractor involved in the effort was Litton Airtron of Morris Plains, New Jersey which did engineering development work during Phase II. The polarizer design was similar in function and form to a polarizer developed by R. Ward of Scotland, that is presently available only from a single foreign source (Ferranti Industrial Electronics Ltd. of Dundee, Scotland) which holds the design propriety.

The subcontractor completed a production readiness review culminating in a production lot sample of 50 polarizers. A complete set of manufacturing documentation and a flow plan with labor distribution was provided. The polarizers were inspected at Litton Laser Systems using a government approved quality plan and were found in general to satisfy all technical requirements.

Currently production orders of laser polarizers from the subcontractor are being shipped to Litton Laser Systems.

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FINAL TECHNICAL REPORT

1.0 INTRODUCTION

All military lasers now being produced by Litton Laser Systems (LLS) use a polarizer developed by R. Ward of Scotland, that is presently available only from a single foreign source (Ferranti Industrial Electronics Ltd. of Dundee, Scotland) which holds the design proprietary. The purpose of this contract was to develop two U.S. sources for the polarizer. The design concept for the high energy laser polarizer is depicted in Figure 1 with some key specifications. The Phase III contract goal was to prove that the subcontractor was capable of producing a cost effective large production run (50 polarizers) and document all manufacturing processes.

Phase III effort was begun in March 1987 and the technical effort was completed on 20 January 1988.

The Phase III subcontract effort was continued from Phase II by Litton Airtron of Morris Plains, New Jersey. Subcontract efforts were monitored by LLS. Suggestions were made concerning manufacturing processes and testing support was given by LLS.

Airtron delivered a complete set of manufacturing process documentation before conducting the pilot production run. A flow plan was also provided which detailed the anticipated labor hours and yields expected at each operation.

Airtron's production coating run was a success except for the first attempts at final assembly of the polarizers. Airtron experienced some instabilities in their instrumentation which until resolved did not allow any consistent assembly of polarizers which met the p polarization requirements. With some work a repeatable stable system was finally achieved and Airtron shipped 50 fully assembled polarizers.

2.0 POLARIZER TECHNICAL SPECIFICATION

The technical specification is attached to this report as Appendix A. The specification was updated before the beginning of the Phase III work. The primary changes were consolidating the prism half and assembly drawings so surfaces are consistent between drawings and are more precise in exactly how surface quality is verified.

3.0 PRISM FABRICATION AND INSPECTION

Airtron was given long lead funding to procure prisms for both Phases II and III. The justification for this was cost and schedule improvement. Fifty (50) prisms from Precision Optics and one hundred and thirty three (133) prisms from Willis Optical were received and inspected. It was apparent that Precision Optics has superior fabrication capabilities with 100% acceptance on all tests. Prisms from Willis Optical have problems with surface defects and a substantial rejection rate of about 37%, for perpendicularity between faces A & B.

The following inspection guidelines were followed for inspecting incoming prisms. The referenced Standard Inspection Procedures (SIP's) are attached as Appendix B.

STANDARD INSPECTION PROCEDURES FOR PRISMS

The following inspection procedures were incorporated to characterize LLS Prism Material, dimensions and optical qualities:

1. Drawing per MIL-STD-34, dimensions and tolerances per ANSI Y14.5.
2. Element in accordance with MIL-O-13830.
3. Material: BK7, Type 517-642, Class 1, Grade A, Fine Annealed in accordance with MIL-G-174.
4. Clear Aperture: 0.375" min.
5. Surface Flatness (at 0.633 um): $\lambda/10$ surfaces A and B, $\lambda/20$ on D.
6. Surface Quality (scratch/dig): Control zone 20/10.
7. Faces A, B, C perpendicular to within 2 arc minutes. Pyramid less than 30 arc seconds.
8. Wavefront distortion: Less than $\lambda/4$ for throughput beam control zone at 0.633 um.
9. Chamfer: .010 x 45° all edges.
10. Light paths within the central zone to be free from internal defects.

1. The prism thickness, measured between the two ground surfaces, was inspected with a Mitutoyo Combimike micrometer (accuracy = .0001") LLS Specification: .500" ± .020. Lengths of prism faces A and B were measured with a Nikon Model #6-C Profile Projector (accuracy = .0001"). LLS Specification: Face = .579" ± .020, Face B = .497" ± .020. The angle between prism faces A and D were inspected following Airtron Standard Inspection Procedure #15 or SIP 22.

2. All inspection procedures mentioned are in compliance with MIL-O-13830A which supersedes MIL-O-13830.

3. Material was "....manufactured in accordance with the applicable drawings, specifications, and purchase order requirements,..." as stated in attached COC received from providers, Willis Optical and Precision Optical.

4. Clear aperture specifications were observed in testing specifications #5, 6, 8 and 10.

5. Surface flatness was inspected following Airtron Standard Inspection Procedure #13.

6. Surface quality was visually inspected with a Nikon Model #78006 Microscope and Army Scratch/Dig Standards DRSMC (D), Form 1107.

7. Perpendicularity was inspected following Airtron Standard Inspection Procedures #16 and #17 and peremodality using SIP #22.

8. Wavefront Distortion was inspected following Airtron Standard Inspection Procedure #14.

9. Chamfer was visually inspected with a Nikon Model #6-C Profile Projector (accuracy = .0001").

10. Internal defects in the light paths were visually inspected with a Nikon Model #78006 Microscope.

4.0 COATING DESIGN

4.1. Anti-Reflection (AR) Coating

Airtron uses two different AR coatings, one for the entrance and exit faces and one optimized for S polarization on the 13 degree angle exit faces. The designs are listed in Table 1. Their performances are graphed in Figures 2 and 3. Each graph includes a dark line which is the nominal design and several dashed lines which represent possible errors in index and thickness of each layer.

4.2 Polarization Coating

The design Airtron used was the same design, LLS-6, which Airtron used as the final design during Phase II. This design features half wave layers of SiO2 on either side of a 7-layer stack on each hypotenuse face with an optimum air gap of 650 nm. The design is listed on Table 2. The angle and air gap error sensitivity are graphed in Figures 4 and 5 respectively, along with performances of two other designs considered during Phase I. A random error analysis is shown in Figure 6. This design and the others considered during Phase I are compared to the laboratory measurements of a standard Ward polarizer in Table 3. For more information on the other designs see the Phase I final report. The pads controlling the air gap are Four .075" inch deposited pads placed on the corners of one prism hypotenuse outside the clear aperture. The pads are vacuum deposited Ta_2O_5 monitored at 1064 nm.

TABLE 1. AIRTRON AR COATING DESIGNS

A. Entrance and Exit Face Design

Layer	Material	Thickness(nm)	Index	Wavelength*(nm)
Substrate	BK-7	--	1.50664	--
1	SiO_2	366.9	1.45	1124
2	Ta_2O_5	52.9	2.035	1124
3	SiO_2	230.9	1.45	1124

B. 13 Degree Reflection Face Design

Layer	Material	Thickness(nm)	Index	Wavelength*(nm)
Substrate	BK-7	--	1.50664	--
1	SiO_2	364.4	1.45	1064
2	Ta_2O_5	53.95	2.035	1064
3	SiO_2	233.8	1.45	1064

* Coating Monitor Wavelength

TABLE 2. AIRTRON POLARIZATION COATING DESIGN

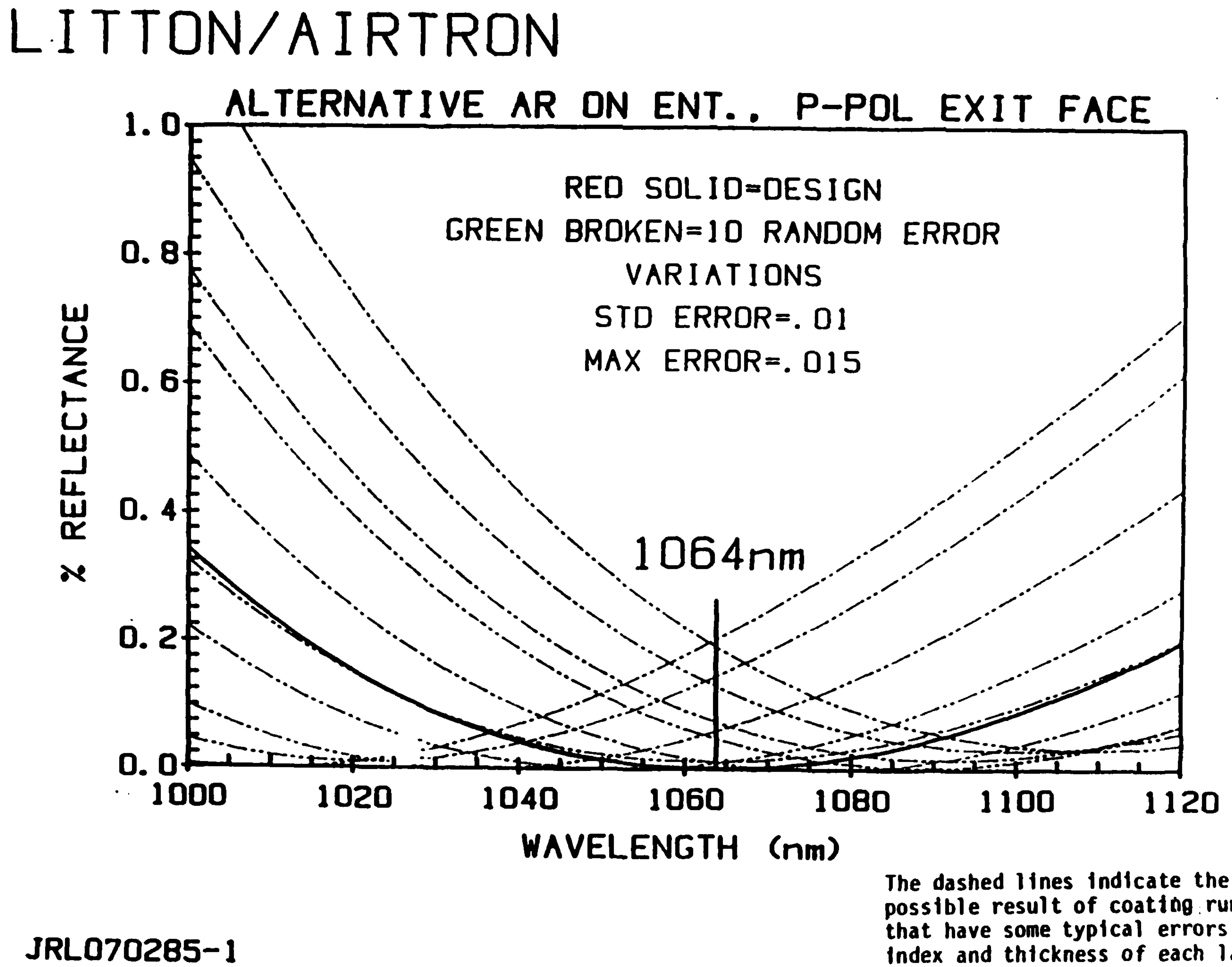
Design Name: LLS-6

Layer	Material	Thickness(nm)	Index	Wavelength*(nm)
Substrate	BK-7	--	1.50664	--
1	SiO_2	505.2	1.45	1465
2	Ta_2O_5	180.0	2.035	1465
3	SiO_2	252.6	1.45	1465
4	Ta_2O_5	180.0	2.035	1465
5	SiO_2	252.6	1.45	1465
6	Ta_2O_5	180.0	2.035	1465
7	SiO_2	505.2	1.45	1465
8	Air	650.0	1.0	1064
9	SiO_2	505.2	1.45	1465
10	Ta_2O_5	180.0	2.035	1465
11	SiO_2	252.6	1.45	1465
12	Ta_2O_5	180.0	2.035	1465
13	SiO_2	252.6	1.45	1465
14	Ta_2O_5	180.0	2.035	1465
15	SiO_2	505.2	1.45	1465
Substrate	BK-7	--	1.50664	--

* Coating Monitor Wavelength

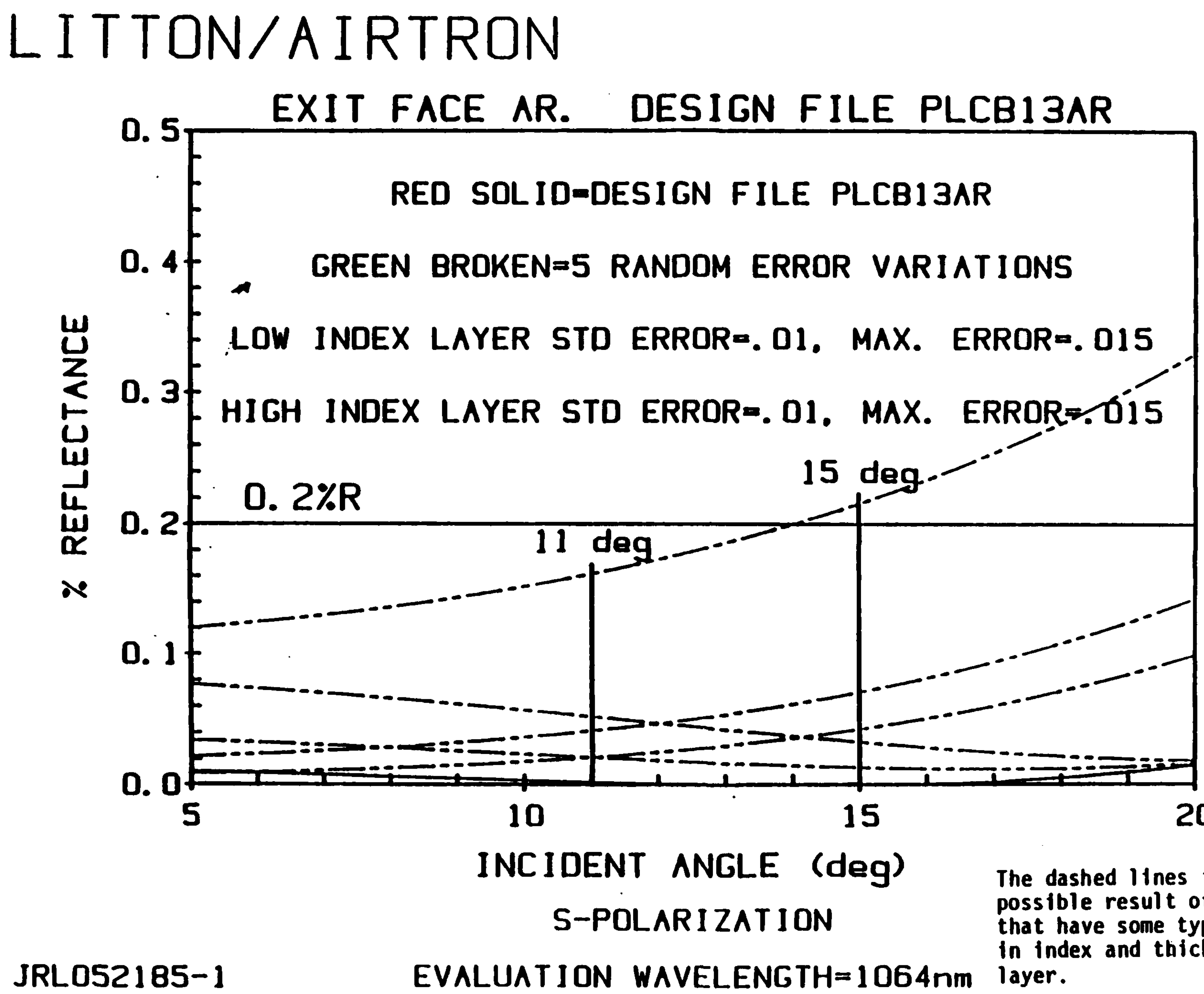
Table 3. AIRTRON COATING DESIGN COMPARISON

Design	Angle	Tp(>98%)	Tp/Ts(>150)	Rs(>98%)	
Ward (Typical)	0°	99.2	294	99.7	
	-0.5°	98.7	312	99.7	
	-1°	97.9	333	99.7	
Airtron	0°	99.9	1,753	99.9	Complicated Sensitive Design
	-0.5°	100.0	2,083	100.0	
	-1°	99.8	2,376	100.0	
LLS-3	0°	99.9	2,855	100.0	Low Laser Damage Threshold
	-0.5°	100.0	3,704	100.0	
	-1°	99.8	4,751	100.0	
LLS-6 (Final)	0°	100.0	735	99.9	
	-0.5°	100.0	847	99.9	
	-1°	99.9	1,030	99.9	



The dashed lines indicate the possible result of coating runs that have some typical errors in index and thickness of each layer.

Figure 2. Airtron 0 Deg. AR Coating Theoretical Performance



The dashed lines indicate the possible result of coating runs that have some typical errors in index and thickness of each layer.

Figure 3. Airtron 13 Deg. AR Coating Theoretical Performance

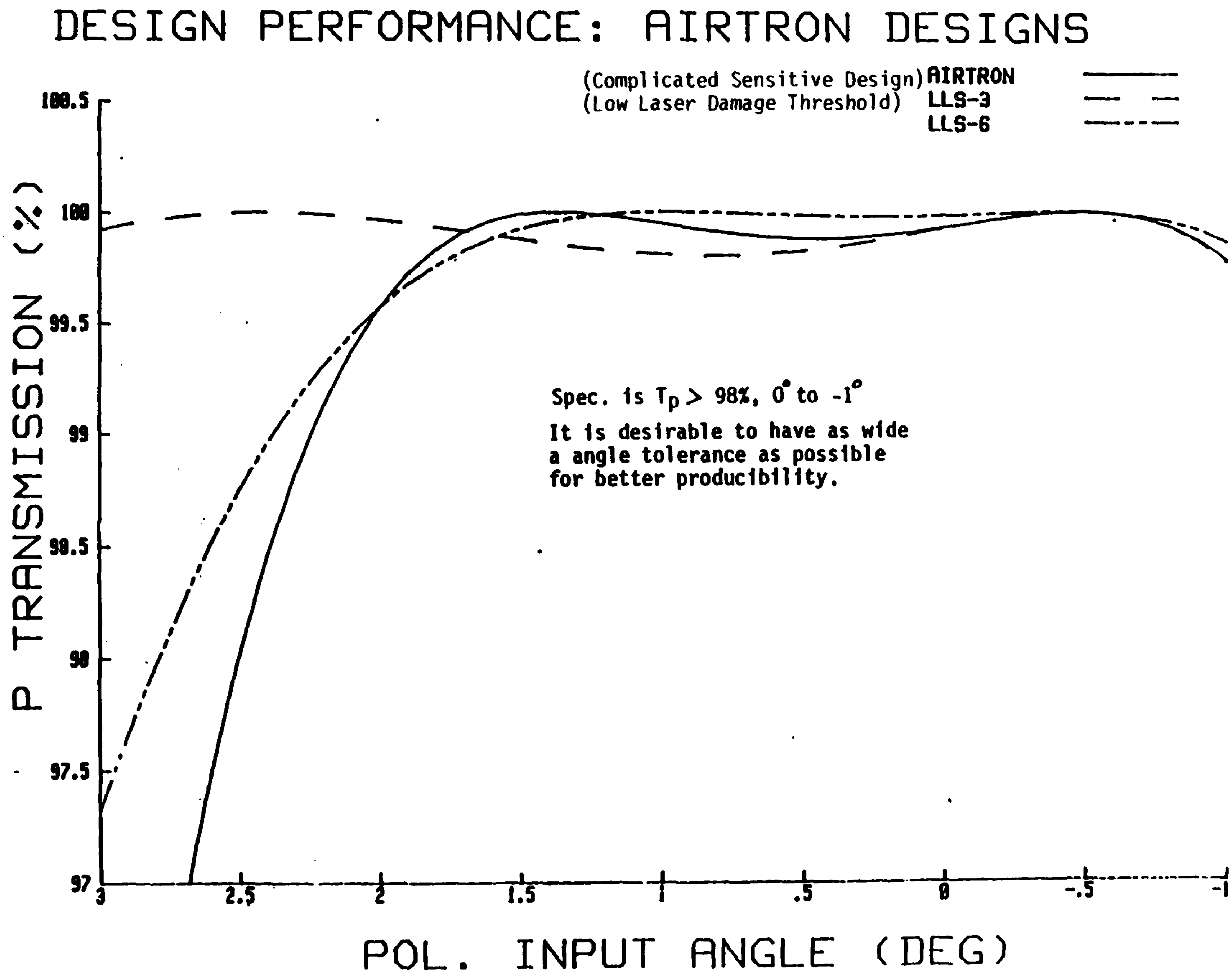


Figure 4. Airtron Polarization Designs Angular Response

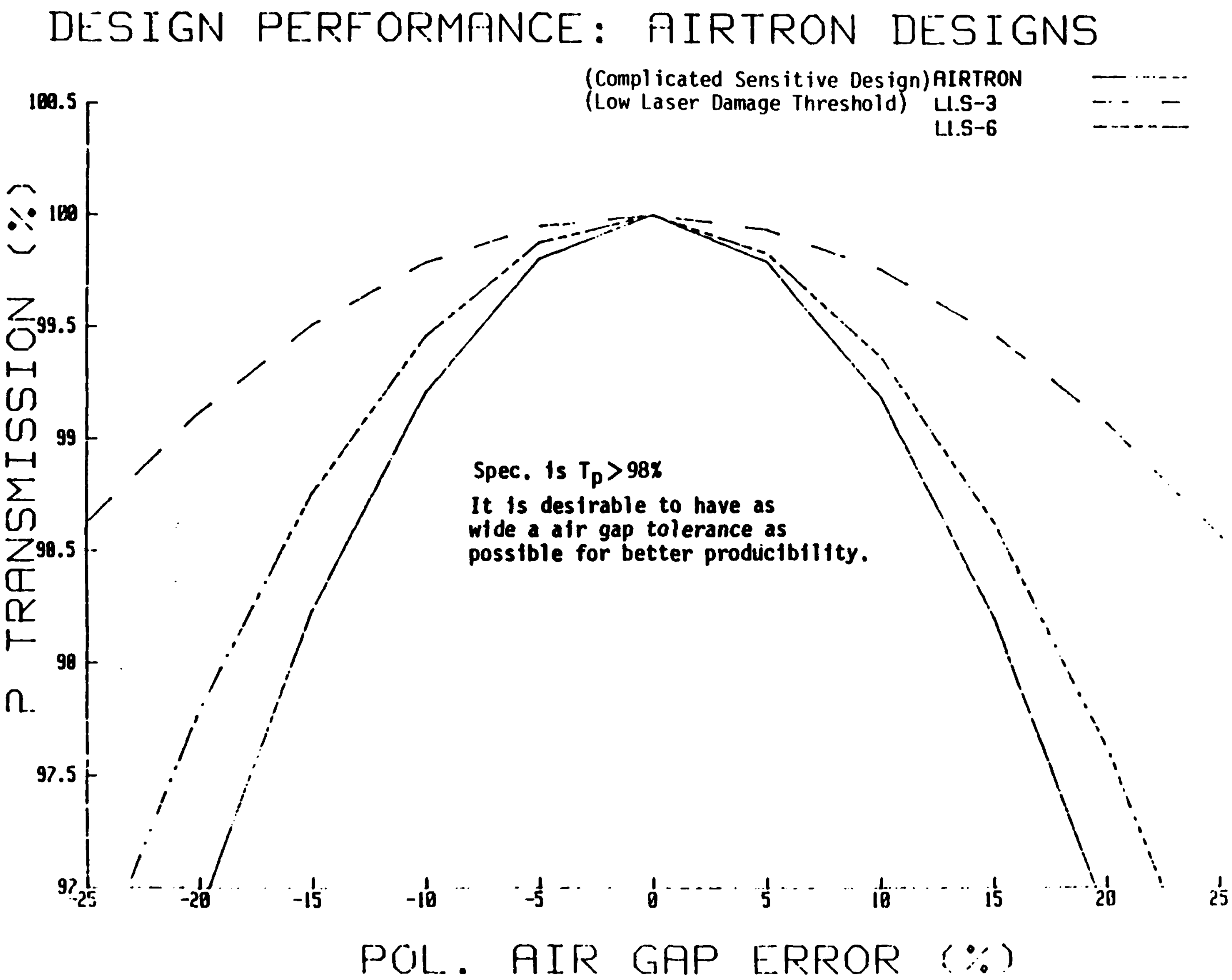


Figure 5. Airtron Polarization Designs Air Gap Error Response

LITTON/Airtron
LASER ELECTRO OPTICS GROUP

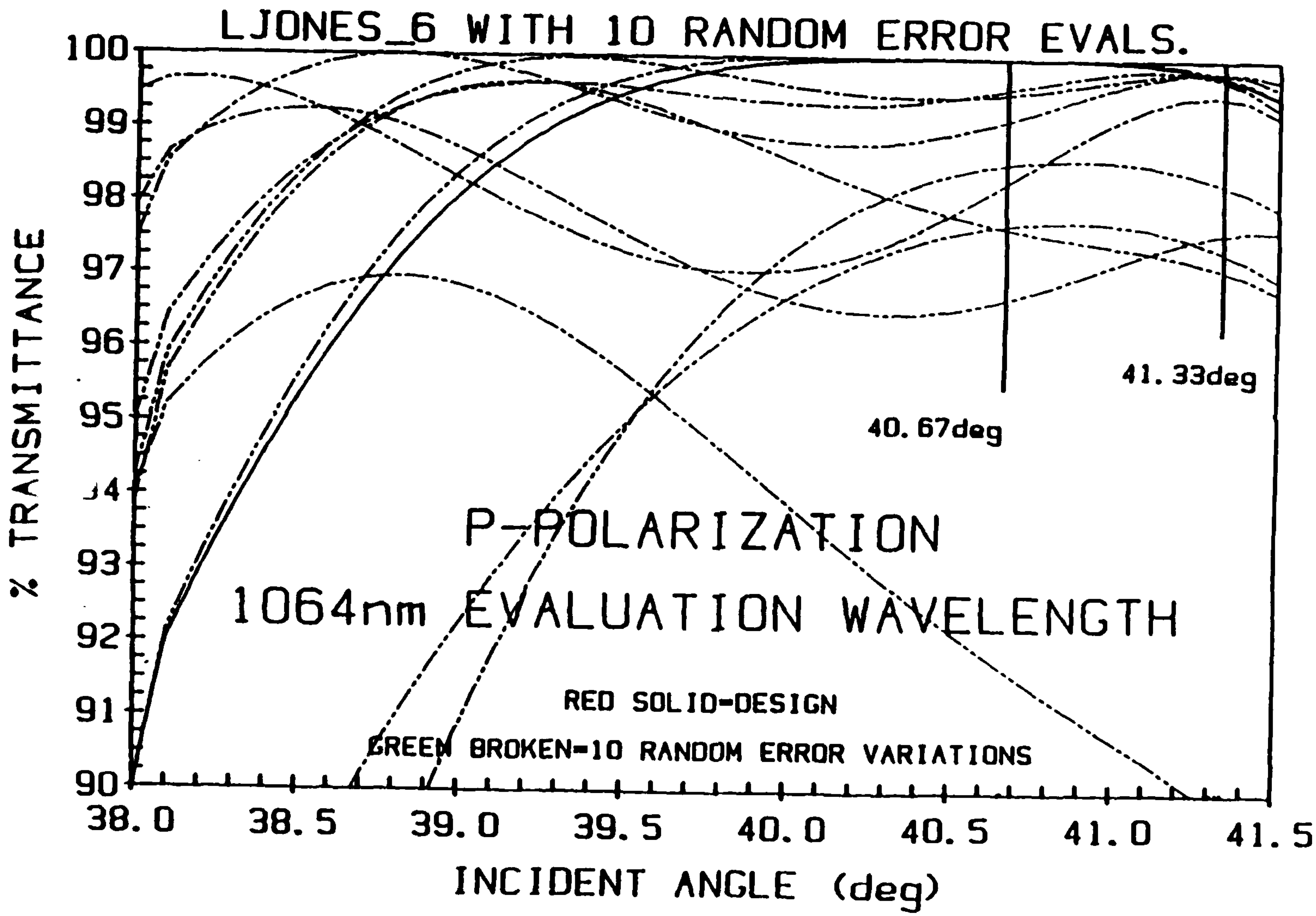


Figure 6. Airtron Polarization Coating Random Error Analysis, Design: LLS-6

The dashed lines indicate the possible results of coating runs that have some typical errors in index and thickness of each layer.

5.0 ASSEMBLY PROCESS

Airtron has submitted a set of inspection and manufacturing process plans attached as Appendix B. The process plans are complete and cover each step of the manufacturing of a polarizer that meets the technical specifications of this contract. A manufacturing flow plan that describes the sequence of operations is discussed in section 7.0.

6.0 TEST

Detailed results are contained in the Quality Inspection Test Demonstration and Evaluation Report for High Reliability Laser Polarizers, CDRL D002. Forty-nine of the fifty polarizers met all polarization requirements, one failed marginally at a limit of angular extent (-1°). Two polarizers were found to have incomplete seals, the bond line did not completely follow the perimeter. Thirteen polarizers were fabricated with Phase II tooling which had air gap separator pads which intrude into the enlarged clear apertures of Phase III. As they are in every sense functionally acceptable, this infraction is considered developmental.

6.1 Polarization Results

Performance of the 50 pilot production run polarizers are shown in Tables 4, 5, 6, 7, and 8. One polarizer was environmentally tested with results given in Table 9. A single polarizer marginally failed the P transmission requirement as measured. Given the instabilities which plagued both Airtron and LLS in the measurement systems, the successful assembly of these components required a higher level of concentration on process than is expected to be required in volume production. Improved measurement stability is being achieved by incorporating more stable sources (diode pumped laser) and calibrating the ratiometer chopper to stabilize detector performance. The test equipment is detailed in the Phase I report.

6.2 Laser Damage Testing

Laser power damage threshold test results are given in Table 10. One cube polarizer which passed all ambient testing was tested. The test was conducted using a pulsewidth of 20 nsec and beam that was "P" polarized in relationship to the polarizer. This "P" polarization state was chosen because it is typically worst case for laser damage threshold on polarizers.

6.3 Humidity Testing

One polarizer which passed all ambient testing was 24 hr humidity tested per MIL-STD-810C. The polarizer was then retested and no degradation in performance was seen.

Table 4. POLARIZER POLARIZATION RESULTS
MM&T TESTING

S/N	Angle	Tp(>98%,-1°-0°)	Tp/Ts(>300,-1°-0°)
	0°	98.3	952
112	-.5°	98.6	1123
	-1°	99.3	1250
	0°	99.0	735
114	-.5°	99.3	793
	-1°	99.7	847
	0°	98.0	1111
125	-.5°	99.0	1219
	-1°	99.7	1351
	0°	99.7	1063
127	-.5°	99.0	1219
	-1°	99.3	1351
	0°	98.3	1008
133	-.5°	99.0	1128
	-1°	99.3	1249
	0°	99.0	961
134	-.5°	99.3	1042
	-1°	99.0	1136
	0°	99.0	909
136	-.5°	99.7	961
	-1°	99.7	1089
	0°	98.0	926
140	-.5°	98.6	1020
	-1°	99.0	1136
	0°	99.7	820
143	-.5°	98.6	909
	-1°	99.3	1020
	0°	99.0	909
145	-.5°	99.0	1042
	-1°	99.3	1162

Table 5. POLARIZER POLARIZATION RESULTS
MM&T TESTING (CONT'D)

S/N	Angle	Tp(>98%,-1°-0°)	Tp/Ts(>300,-1°-0°)
151	0°	98.6	769
	-.5°	99.0	862
	-1°	98.0	961
152	0°	99.7	781
	-.5°	98.6	862
	-1°	98.6	961
156	0°	98.6	649
	-.5°	98.6	704
	-1°	99.0	769
171	0°	98.0	781
	-.5°	98.6	862
	-1°	99.3	926
172	0°	98.3	781
	-.5°	98.3	862
	-1°	99.3	961
179	0°	99.3	806
	-.5°	99.7	877
	-1°	98.6	961
180	0°	99.0	980
	-.5°	99.0	1111
	-1°	99.3	1282
464	0°	99.5	800
	-.5°	99.2	800
	-1°	98.0	800
188	0°	98.7	1020
	-.5°	98.7	1219
	-1°	96.7	1351
189	0°	98.7	1089
	-.5°	98.7	1282
	-1°	97.7	1428

Table 6. POLARIZER POLARIZATION RESULTS
MM&T TESTING (CONT'D)

S/N	Angle	Tp(>98%,-1°-0°)	Tp/Ts(>300,-1°-0°)
	0°	99.7	1250
190	-.5°	99.7	1428
	-1°	99.0	1562
	0°	99.3	1250
192	-.5°	99.3	1470
	-1°	98.3	1667
	0°	99.0	1282
194	-.5°	98.7	1515
	-1°	97.3	1724
	0°	99.7	1250
196	-.5°	99.3	1470
	-1°	98.3	1667
	0°	100	1219
198	-.5°	99.3	1389
	-1°	97.4	1613
	0°	100	1250
200	-.5°	99.0	1428
	-1°	97.0	1613
	0°	99.7	1282
202	-.5°	98.7	1470
	-1°	97.3	1667
	0°	99.3	1351
204	-.5°	99.0	1562
	-1°	97.4	1786
	0°	100	1282
207	-.5°	99.3	1515
	-1°	98.7	1724
	0°	99.7	1250
217	-.5°	99.3	1428
	-1°	98.3	1613

Table 7. POLARIZER POLARIZATION RESULTS
MM&T TESTING (CONT'D)

S/N	Angle	Tp(>98%,-1°-0°)	Tp/Ts(>300,-1°-0°)
	0°	99.3	1219
219	-.5°	99.3	1351
	-1°	98.3	1515
	0°	98.6	1351
220	-.5°	98.0	1613
	-1°	97.3	1852
	0°	99.3	1428
223	-.5°	98.7	1667
	-1°	97.7	1923
	0°	99.3	1219
226	-.5°	99.0	1351
	-1°	98.3	1562
	0°	99.7	1162
228	-.5°	99.3	1315
	-1°	99.0	1515
	0°	99.7	1162
229	-.5°	99.3	1315
	-1°	98.3	1470
	0°	99.7	1351
232	-.5°	99.0	1613
	-1°	98.0	1852
	0°	100	1428
234	-.5°	99.3	1667
	-1°	97.0	1923
	0°	99.7	1111
236	-.5°	99.3	1250
	-1°	98.0	1470
	0°	99.7	1136
239	-.5°	99.3	1282
	-1°	98.3	1470

TABLE 9. POLARIZER ENVIRONMENTAL TEST
MM&T TESTING
SERIAL #136

TEMP.	0° INC. ANGLE		-.5° INC. ANGLE		-1.0° INC. ANGLE	
	Tp(>98%)	Tp/Ts(>300)	Tp(>98%)	Tp/Ts(>300)	Tp(>98%)	Tp/Ts(>300)
73°F	98.3	952	99.0	1123	98.7	1250
158°F	99.0	1111	98.7	1250	98.7	1613
-40°F	98.6	980	98.6	1220	98.0	1389

TABLE 10. LASER POWER DAMAGE TEST
SERIAL #133

POLARIZATION	SPECIFICATION	DAMAGE THRESHOLD
S	500 MW/cm²	646 MW/cm²
P	500 MW/cm²	501 MW/cm2

7.0 MANUFACTURING FLOW PLAN

Attached is Appendix C which is the manufacturing flow chart for making a high energy laser polarizer. The flow chart has indicated on it the processes needed for each step. Also indicated on the chart are the cumulative fractional yields after each process step. The estimated worst case fractional final yield is indicated as 0.5. The labor unit hours and cumulative labor unit hours per polarizer are also indicated on the chart. The man hours per polarizer are estimated at 5.5 hours.

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APPENDIX A

LASER POLARIZER SPECIFICATION

29 JANUARY 1988

1.0 ITEM DEFINITION

The polarizer shall be a "cube" polarizer assembly, having the configuration shown in Figure 1. The polarizer assembly shall consist of two prisms, each having the configuration shown in Figure 2. These prisms shall be coated on four faces (A, B, C and D of Figure 1) for low reflection of 1.064μm light and on the hypotenuse face for polarization of 1.064μm light. Pads shall also be deposited on the hypotenuse face of either one or both prisms to achieve the accurate air gap between assembled prisms required by the polarization coating design. The prisms shall be assembled with an edge application of cement which shall bond and seal the assembly.

2.0 PHYSICAL CHARACTERISTICS

Physical characteristics of the polarizer assembly and the constituent prisms shall be as given in Figures 1 and 2. All dimensions are in inches. Polarizer shall be completely edge sealed with an appropriate bonding agent that will allow the assembled polarizer to meet the requirements of this specification.

3.0 OPTICAL QUALITY

The polarizer assembly shall conform to the following optical quality requirements in the clear aperture paths:

a. Surface flatness on surfaces A, B, C, and D (at 0.633μm): better than $\lambda/10$.

b. Surface scratch/dig: 20/10 per paragraphs 3.2 and 3.3 of attached LLS PAI OP012 (last revised 4/17/87).

c. Throughput wavefront distortion (at 0.633μm): less than $\lambda/4$.

d. Evidence of streaks, smears, stains, blotchiness or discoloration on an exterior surface or internal surfaces shall be cause for rejection if:

   1) The polarizer fails the requirements of paragraph 5.0; or
   2) The polarizer fails the requirements of paragraph 6.0.

4.0 BEAM ANGLE TOLERANCE

At room temperature, the output beam angles from the polarizer assembly shall conform to the following requirements when tested with a 0.633μm input beam:

a. Transmitted beam: Deviation less than 2 arc minutes form the input beam.

b. Reflected beam: Deviate less than 4 arc minutes from a plane containing the normals of surfaces A and B, when the input beam is normal to entrance surface A.

5.0 POLARIZATION PERFORMANCE

5.1 The polarizer assembly shall conform to the following polarization performance requirements when tested at 1.064μm.

a. T_p (see note 8.1): >98%

b. T_p/T_s (see note 8.2): >300

c. R_s (see Note 8.3): >98%

d. R_s/R_p (see note 8.3): >50

e. Acceptance angle: The T_p, T_s and R_s performance shall be achieved over at least the 0.5 ±0.5 degree input angle defined in Figure 1.

5.2 ANTIREFLECTION COATINGS

1. Surface A and C coating per MIL-F-48616.
   Type: Antireflection for lamda = 1.064μm incident at 0° ±5°.

2. Surfaces B and D coating per MIL-F-48616.
   Type: Antireflection for lamda = 1.064μm incident at 13° ±2°.

6.0 LASER POWER DENSITY TOLERANCE

The polarizer assembly shall not be damaged by laser pulses of 20 ±5 nanoseconds nominal pulsewidth and peak power density of: 500 MW/cm^2

7.0 ENVIRONMENTAL PERFORMANCE

7.1 <u>Operating Environment</u>

In the environments specified below, the polarizer assembly shall achieve the polarization performance of paragraph 5, and the beam angles of paragraph 4 shall vary less than ±20 arc seconds:

a. High temperature: +160°F (+71°C)

b. Low temperature: -40°F (-40°C)

7.2 **Non-Operating Environment**

After exposure to the environments specified below, the polarizer assembly shall achieve the polarization performance of paragraph 5, and the beam angles of paragraph 4 shall vary less than ±20 arc seconds:

a. Temperature cycling: -67°F to +160°F (-55°C to +71°C)

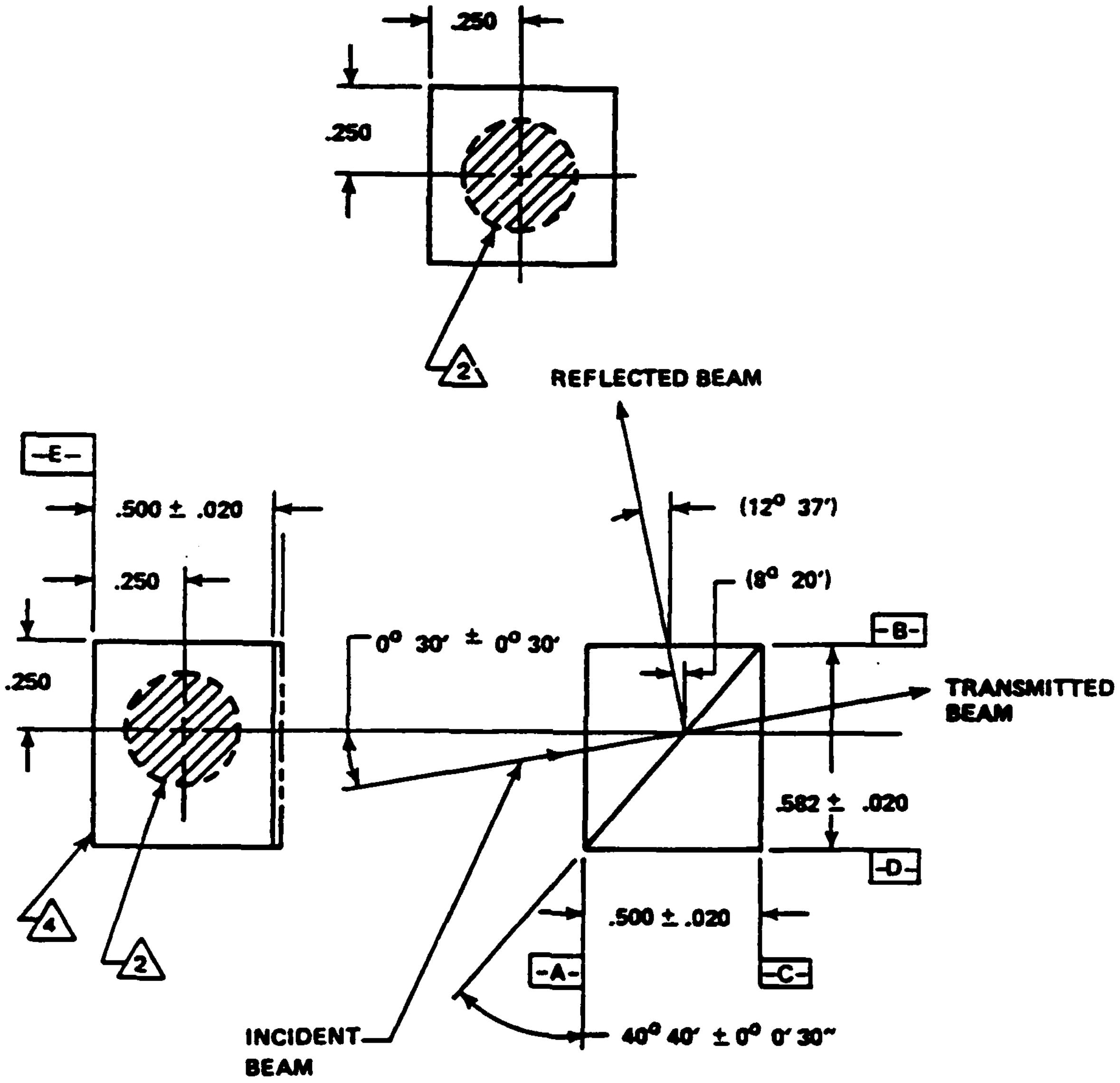
b. $\geq$95% relative humidity (no condensation)

8.0 NOTES

8.1 P-plane Transmission (T_p): P-plane polarization orients the electric field vector of the input beam parallel to the plane of the input and reflected beams. T_p is defined as the ratio of transmitted beam power to input beam power for P-plane polarization of the input beam.

8.2 S-plane Transmission (T_s): S-plane polarization orients the electric field vector of the input beam perpendicular to the plane of the input and reflected beams. T_s is defined as the ratio of transmitted beam power to input beam power for S-plane polarization of the input beam.

8.3 S-plane Reflection (R_s): R_s is defined as the ratio of reflected beam power to input beam power for S-plane polarization of the input beam.

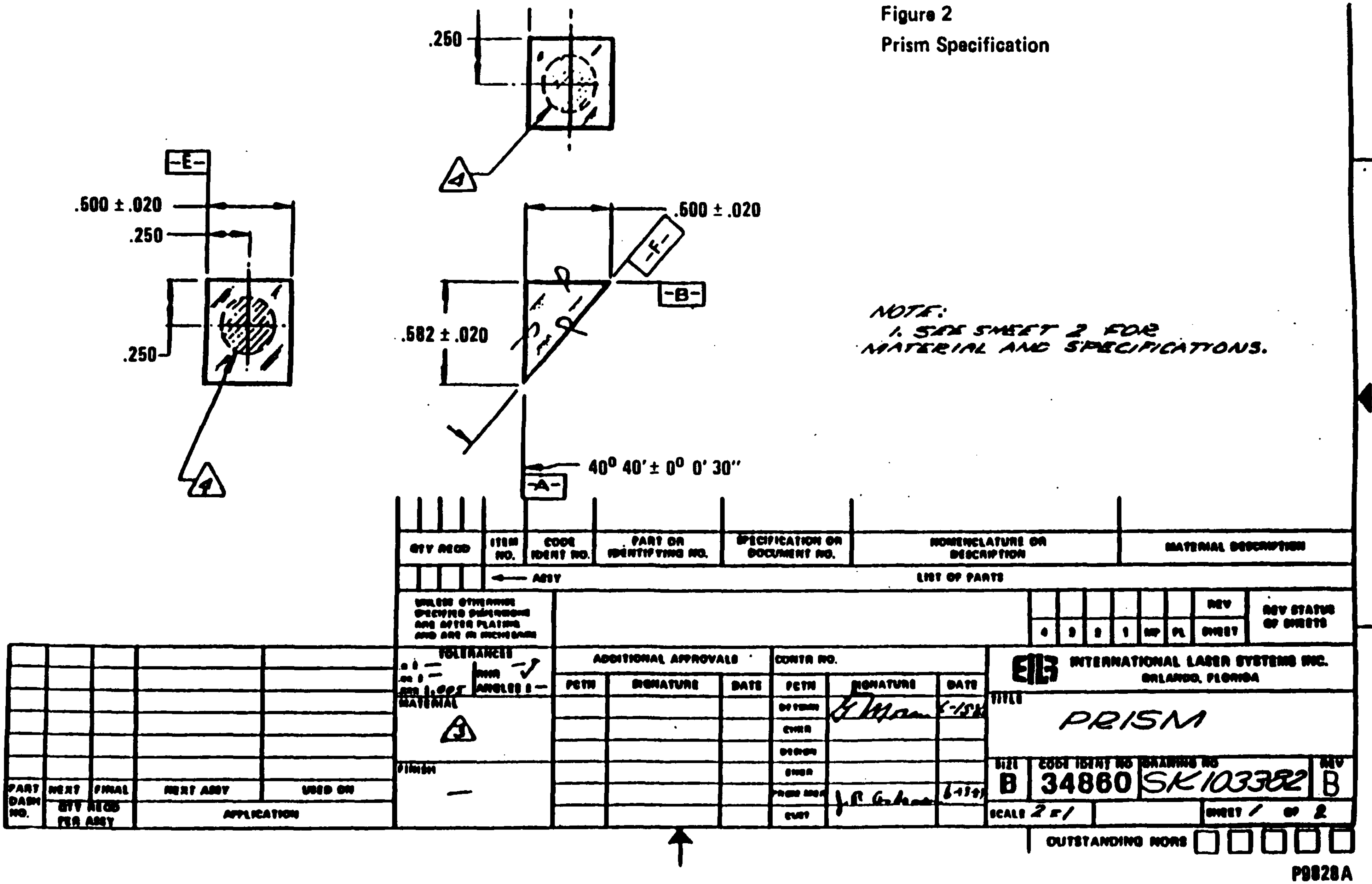


NOTES:

1. MATERIAL: BK-7
2. CLEAR APERTURE: 0.375 MIN.
3. CHAMFER: 0.015 MAX x 45° ALL EDGES
4. MISMATCH: 0.005 MAX

Figure 1
Polarizer Assembly

Figure 2
Prism Specification



SPECIFICATIONS

1. Drawing per MIL-STD-34, dimensions and tolerances per ANSI Y14.5.
2. Element in accordance with MIL-O-13830.
3. Material: BK 7, Type 517-642, Class 1, Grade A, Fine Annealed in accordance with MIL-G-174.
4. Clear Aperture: 0.375 min.
5. Surface Flatness within the clear aperture (at 0.633μm): Surfaces A and B: $\lambda/10$, Surface F: $\lambda/20$.
6. Surface Quality (scratch/dig): Control Zone 20/10.
7. Faces A, B, E perpendicular to within 2 arc minutes.
8. Pyramid within 30 arc seconds.
9. Wavefront Distortion: Less than $\lambda/4$ for throughput beam clear aperture at 0.633μm.
10. Chamfer: .015 x 45° all edges.
11. Light paths within the clear aperture to be free from internal defects.

SK103382 Rev. B
Prism
Sheet 2 of 2

Laser Systems

Litton

Product Assurance Instructions

Subject :

SURFACE COATING QUALITY INSPECTION

Number :

OP 012

REVISION STATUS OF PAGES

SH	INIT.	REV A	REV B	REV C	REV D	REV E	REV F	REV G	REV H	REV I	REV J	REV K	REV L	REV M
1	1/12/81	8/20/84	8/1/85	8/8/86	8/21/86									
2	1/12/81	8/20/84	8/1/85	8/28/85	8/8/86	8/21/86								
3			8/1/85	8/8/86	8/21/86									
4			8/1/85	8/8/86	8/21/86									
5	8/8/86	8/21/86												
6	8/8/86	8/21/86												
7	8/8/86	8/21/86												
8	8/8/86	8/21/86	10/17/86	4/17/87										
9	8/8/86	8/21/86	10/17/86	4/17/87										
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11	8/8/86	8/21/86	10/17/86	4/17/87										
12	8/8/86	8/21/86	10/17/86											
13	8/8/86	8/21/86												
14	8/8/86	8/21/86												
15	8/8/86	deleted												
16	8/8/86	deleted												

100885-03

3.2 Scratch & Dig Inspection Procedure

3.2.1 General

3.2.1.1 Scope

This procedure establishes the method for locating and defining scratches and digs found on the optical surfaces and coatings.

3.2.1.2 Purpose

The purpose of this procedure is to classify optical surface scratches and digs using low power magnification visual inspection and comparison for acceptance to the Surface Quality Scratch and Dig Standards of MIL-0-13830 and C7641866.

3.2.2 Scratch and Dig Inspection Requirements

The inspection for scratches and digs will be performed simultaneously as prescribed in this procedure.

APPENDIX B

INSPECTION AND MANUFACTURING PROCESS PLANS

29 JANUARY 1988

3.2.2.1 Equipment List

The following equipment is required in the performance of this procedure:

a. High intensity lamp, American Optical, Model 655 or equivalent.

b. 3X to 10X stereo microscope or equivalent.

c. C7641866, Surface Quality Standards for Optical Elements.

d. Finger cots, Cleanroom approved washed latex.

e. Nylon gloves, Cleanroom approved.

f. Industrial microscope, Leitz Model SM-LUX-HL with Toolmakers Translation Stage or equivalent; or 7X or greater optical eyeloop with measurement reticle.

3.2.2.2 Definitions

The following definitions shall apply to this procedure.

a. Scratch - Any marking or tearing of this surface. Scratch types are identified as follows:

   1. Block Reek - Chain like scratch produced by polishing.

   2. Runner-Cut - Curved scratch caused by grinding.

   3. Sleek - Hairline scratch.

   4. Crush or Rub - Surface scratch or a series of small scratches, generally caused by mishandling.

b. Dig - A small rough spot on the optical surface similar to pits in appearance, generally caused by mishandling.

c. Clear Aperture (CA) - A circular area of specified diameter that is equivalent to the largest beam (i.e.; bundle of light rays) incident on the specified surface. Diameter of the CA is specified as an optical element design parameter.

3.2.2.3 Terms and Abbreviations

Only those terms and abbreviations in common usage are used herein.

3.2.3 Detailed Scratch and Dig Inspection Procedure

3.2.3.1 Handling

Clean nylon gloves with the fingers covered with clean talc-free surgical rubber finger cots shall be worn when performing any operation in this procedure.

3.2.3.2 Visual Inspection Procedure

Using high intensity specular illumination and the stereo microscope at <10X:

a. Visually examine each optical surface of the component.

b. Classify each scratch and dig observed by comparison with the standards of C7641866.

c. Assign a "Scratch Number" to each scratch as compared with the standards of C7641866. Record this number. A scratch sizes between two standard numbers shall be assigned the lower number. Isolated or singular circular chips along a scratch shall be evaluated as digs and shall not be considered in assigning a scratch number.

d. Assign a "Dig Number" to each dig as compared with the standards of C7641866. Record this number. A dig of a size between two standard numbers shall be assigned the lower number. The diameter of irregular shaped digs shall be taken as one half the sum of the maximum length and the maximum width.

3.2.3.3 Scratch Length Measurement

Using the toolmakers microscope at >7X, measure the length of each scratch for which a "Scratch Number" was assigned and recorded. Record these values on the data sheet adjacent to the corresponding "Scratch Number".

3.2.4 Acceptance Criteria

3.2.4.1 Scratches

Cumulative scratch number is calculated as followed:

$$\sum_{i=1}^{n} Si \qquad \text{where } Si = \frac{NiLi}{D}$$

Ni is scratch number of individual scratches.
Li is the corresponding length of individual scratches.
D is diameter of the element's clear aperture (CA).

Surface scratches are permissible provided the scratch widths do not exceed the specified scratch number. In addition, the following contraints must be satisfied.

3.2.4.1.1 For an Element With No Maximum Size Scratch Observed

The cumulative scratch number for elements with no maximum size scratch observed must not exceed the specified scratch number.

3.2.4.1.2 For an Element With Maximum Size Scratch Observed

The cumulative scratch number for elements with one or more maximum size scratches must not exceed 1/2 of the specified scratch number and the sum of the lengths of maximum size scratches must not exceed 1/4 the diameter of the element's clear aperture.

3.2.4.2 Digs

No dig shall exceed the specified dig number. The number of permissible maximum size dig is one per circle of 20 mm diameter. The sum of dig number of all digs per circle of 20 mm diameter shall not exceed twice the specified dig number.

SUBJECT: SURFACE COATING QUALITY INSPECTION			PREPARED BY: P. Nguyen	
			APPROVED BY: R. Green	
NUMBER: OP 012	REV: C	RELEASE DATE: 04/17/87	EFFECTIVE DATE: 04/17/87	PAGE: 9 of 14

3.3 Chip Inspection

3.3.1 General

3.3.1.1 Scope

This procedure establishes the method for locating and defining chips found along the physical edges of the optical components.

3.3.1.2 Purpose

The purpose of this procedure is to classify edge chips using low power magnification visual inspection and criteria based on MIL-0-13830.

3.3.2 Inspection Requirements

3.3.2.1 Equipment List

The following equipment is required in the performance of this procedure:

a. 3X to 10X stereo microscope.

b. High intensity lamp, American Optical, Model 655 or equivalent.

c. Finger cots, Cleanroom approved washed latex.

d. Nylon gloves, Cleanroom approved.

3.3.2.2 Definitions

The following definitions shall apply to this procedure:

a. Edge Chip - A fracture or break located along a physical edge of an optical part which has broken out and left a smooth "shell-shaped" area.

b. Stoned - A surface which has been roughened to a grey appearance using a stone abrasive material.

c. Clear Aperture (CA) - A circular area of specified diameter that is equivalent to the largest beam (i.e.; bundle of light rays) incident on the specified surface. Diameter of the CA is specified as an optical elements design parameter.

3.3.2.3 Terms and Abbreviations

Only those terms and abbreviations in common usage are used herein:

3.3.3 Detailed Inspection Procedure

3.3.3.1 Handling

Clean nylon gloves with fingers covered with clean talc-free surgical rubber finger cots shall be worn when performing any operation in this procedure.

3.3.3.2 Visual Chip Inspection

Using the stereo microscope at <10X and high intensity specular illumination, visually examine each edge of the glass element. Compare each chip observed that is larger than 1/2 mm (0.020 inch) to the acceptance criteria of paragraph 3.3.4.

3.3.4 Acceptance Criteria

a. Edge chips, which do not encroach on the CA of a surface shall be allowed. Edge chips that intrude into the CA of surface shall be evaluated as digs per procedure 3.2.

b. Edge chips larger that 1/2 mm (.02 inches) as measured at the chips largest extremity, should be stoned to lessen the possibility of additional chipping.

c. The sum of the chip widths larger than 1/2 mm (.02 inches) as measured at the edge, shall not exceed 10 percent of the edge length,'on which the chip is located.

TITLE: TEST METHOD FOR PRISM SURFACE FLATNESS

1.0 **Scope:**

This is a procedure to measure the surface flatness of a polished prism face.
I.L.S. Specification: $< \lambda/10$

2.0 **Reference Documents:**

I.L.S. sketch # SK103382, see Figure #1.

3.0 **Test Equipment:**

Zygo Mark II Interferometer System with Z.A.P.P. (Zygo Automatic Pattern Processor), Zygo Model #DT-3 Aperture Converter, Zygo Model #400 Adjustable Mount with-Reference Flat, Zygo Model #M-401 Adjustable Mount with circular Attachment and Plate.

4.0 **Test Set-up:**

4.1 Set the interferometer to the "align " mode. The monitor will display a set of crosshairs, see Fig.2.

4.2 Position the adjustable mount with reference flat perpendicular to the output beam, see Fig. 3.

4.3 The monitor should display the crosshairs and a bright dot, see Fig. 4.

4.4 Adjust the two axis' of the adjustable mount until the dot is centered on the crosshair.

4.5 Attach the aperture converter to the mainframe of the interferometer, see Fig. 5.

4.6 Remove the output lens of the aperture converter.

4.7 Adjust the two axis' of the aperture converter input lens until the dot is centered on the crosshair.

4.8 Replace the output lens on the aperture converter.

4.9 Adjust the two axis' of the aperture converter's output lens until the dot is centered on the crosshair. The interferometer is now aligned and ready for measuring.

4.10 Remove the adjustable mount with reference flat.

4.11 Position the adjustable mount with circular attachment and plate perpendicular to the output beam, see Fig. 6.

5.0 <u>Test Procedure</u>:

5.1 Place prism face C (ground surface) on the plate and position face A perpendicular to the output beam, see Fig. 6.

5.2 Adjust the two axis' of the adjustable mount until the dot is centered on the crosshair.

5.3 Set the interferometer to the "view" mode.

5.4 Adjust the two axis' of the adjustable mount until parallelism fringes are removed and a multitude of vertically oriented fringes are obtained, see Fig.7.

5.5 Execute Z.A.P.P. measure. The fringe deviations are automatically averaged and the surface flatness is displayed on the monitor in wave units, see Fig.8.

5.6 Repeat steps 5.1 through 5.4 for prism faces B and D, see Fig. 1.

FIGURES FOR S.I.P. #1

FIG. 1

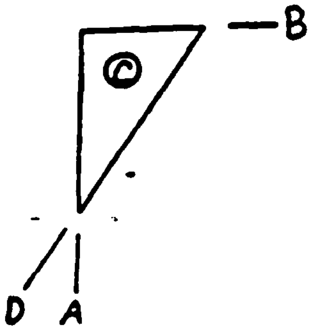


FIG. 2

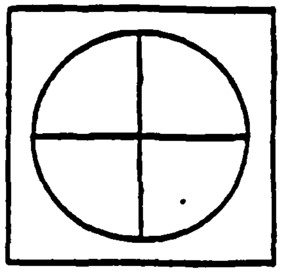


FIG. 3 Side View

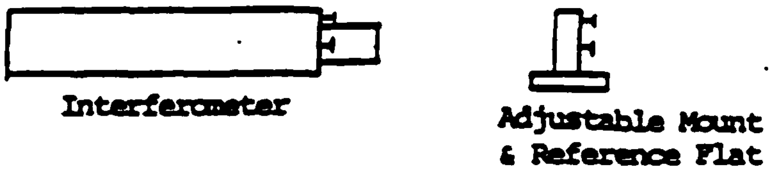


FIG. 4

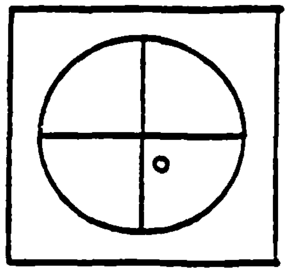


FIG. 5 Side View

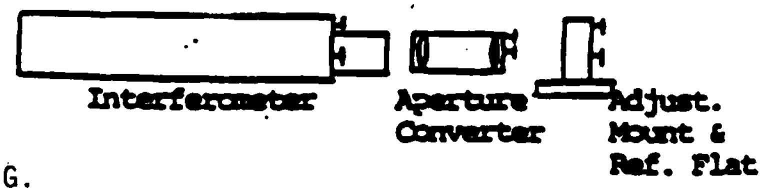


FIG. 6 Side View

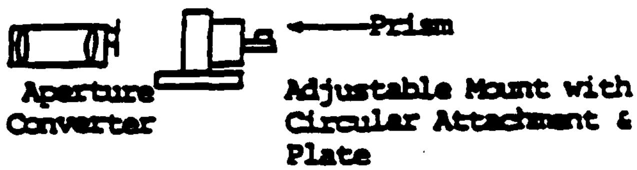


FIG. 7

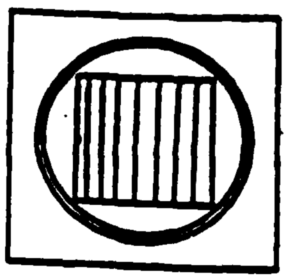
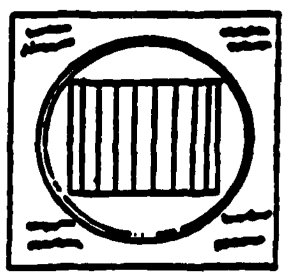


FIG. 8



RESULTS FOR S.I.P. #1

L.L.S. SPEC< $\lambda/10$

		Surface Flatness (wave units)	
Sample Prism #	Side A	Side B	Side D
1	0.05	0.07	0.09
2	0.07	0.08	0.07
3	0.06	0.09	*
4	0.07	0.05	*
5	0.04	0.05	*
6	0.08	0.13	*
7	0.07	0.07	*
8	0.07	0.05	*

* not able to analyze due to interference of retro-reflected fringes

S.I.P. NO: 2

Page: 1 of 4

Date: December 18, 1987

TITLE: TEST METHOD FOR PRISM WAVEFRONT DISTORTION

1.0 Scope:

This is a procedure to measure wavefront distortion through a prism.
I.L.S. Specification: $< \lambda/4$.

2.0 Reference Documents:

I.L.S. Sketch #SK103382, see Fig. 1.

3.0 Test Equipment:

Zygo Mark II Interferometer System with Z.A.P.P. (Zygo Automatic Pattern Processor), Zygo Model #DT-3 Aperture Converter, Zygo Model #M-400 Adjustable Mount with Reference Flat, Zygo Model #M-401 Adjustable Mount with Circular Attachment and Plate.

4.0 Test Set-up:

4.1 Set the interferometer to the "align " mode. The monitor will display a set of crosshairs, see Fig.2.
4.2 Position the adjustable mount with reference flat perpendicular to the output beam, see Fig. 3.
4.3 The monitor should display the crosshairs and a bright dot, see Fig. 4.
4.4 Adjust the two axis' of the adjustable mount until the dot is centered on the crosshair.
4.5 Attach the aperture converter to the mainframe of the interferometer, see Fig. 5.

4.6 Remove the output lens of the aperture converter.

4.7 Adjust the two axis' fo the aperture converter input lens until the dot is centered on the crosshair.

4.8 Replace the output lens on the aperture converter.

4.9 Adjust the two axis' of the aperture converter's output lens until the dot is centered on the crosshair. The interferometer is now aligned and ready for measuring.

4.10 Remove the adjustable mount with reference flat.

4.11 Position the adjustable mount with circular attachment and plate perpendicular to the output beam, see Fig. 6.

5.0 <u>Test Procedure</u>:

5.1 Place prism face C (ground surface) on the plate and position face A perpendicular to the output beam, see Fig. 6.

5.2 Adjust the two axis' of the adjustable mount until the dot is centered on the crosshair.

5.3 Position the adjustable mount with reference flat to return the transmitted/reflected beam back through prism face B, see Fig. 7.

5.4 Adjust the two axis' of the adjustable mount with reference flat until the dot is centered on the crosshair.

5.5 Set the interferometer to the "view " mode.

5.6 Adjust the two axis' of both adjustable mounts until flatness fringes are removed and a multitude of vertically oriented fringes are obtained, see Fig. 8.

5.7 Execute Z.A.P.P. measure. The fringe deviations are automatically averaged and the wavefront distortion is displayed on the monitor in wave units, see Fig. 9.

FIGURES FOR S.I.P. #2

FIG. 1

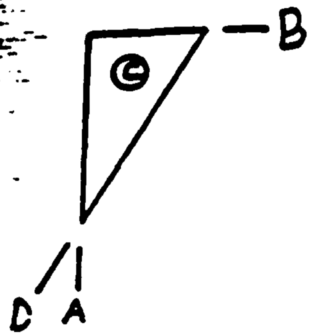


FIG. 2

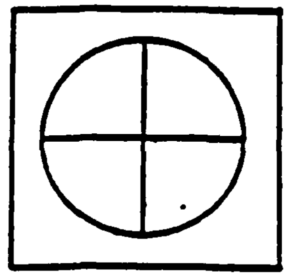


FIG. 3 Side View

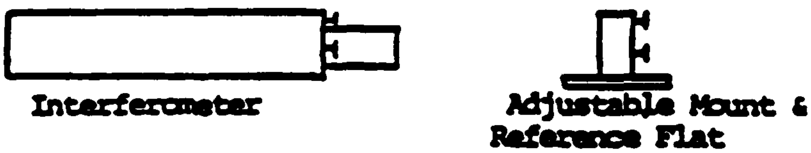


FIG. 4

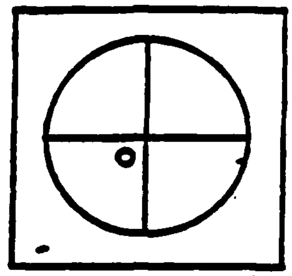


FIG. 5 Side View

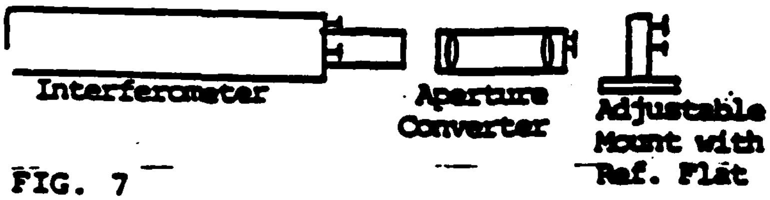


FIG. 6 Side View

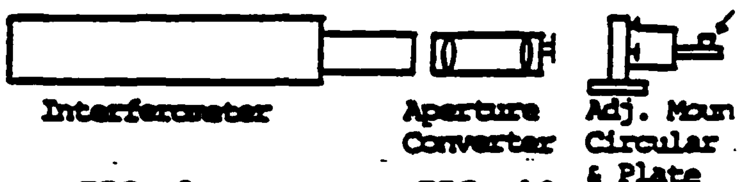


FIG. 7

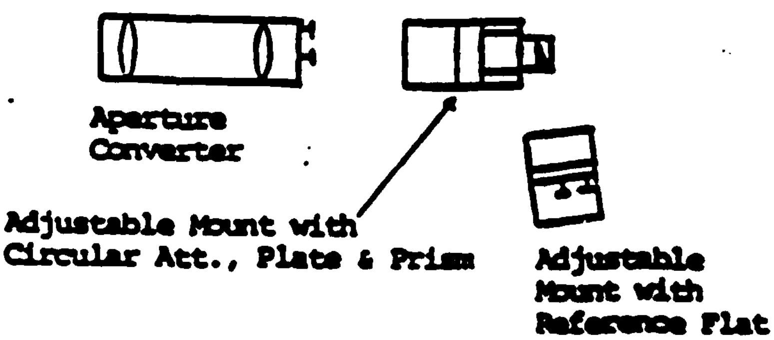


FIG. 9

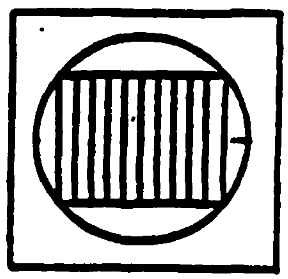
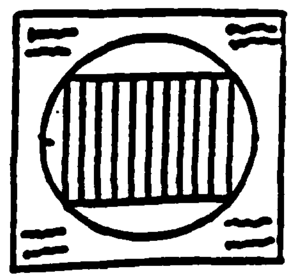


FIG. 10



RESULTS FOR S.I.P. #2

L.L.S. SPEC: < $\lambda/4$

Sample Prism #	Wavefront Distortion (Wave Units)
1	0.06
2	0.09
3	0.14
4	0.07
5	0.05
6	0.16
7	0.09
8	0.05

Date: December 17, 1987

TITLE: TEST METHOD FOR PRISM FACE ANGLE MEASUREMENTS

1.0 Scope:

This is a procedure to measure angle between prism face A and D, see Fig. 1.
I.L.S. Specifications: Angle between A and D: 40°40' ± 1'
Pyramidal Error between A and D: < 2 arc minutes.

2.0 Reference Documents:

I.L.S. Sketch #SK103382, see Fig. 1

3.0 Test Equipment:

Two Nikon Model #3035 Autocollimators; J.A. Noll Model #NPZAB-40 Positioning Device with Newport Model #470 Rotational Stage; Starrett-Weber Angle Gage Blocks (accuracy of ±1 arc second).

4.0 Test Procedure:

4.1 Wring the angle gage blocks together to make an angle of 40°40' and place on the rotational stage.
4.2 Position the autocollimator in the horizontal plane, perpendicular to the A and D sides of the blocks, see Fig.2.
4.3 Adjust the two axis' of the autocollimators until the returned bright crosshairs center on the autocollimators reticle (dark crosshair), see Fig. 3. Now the auto-collimators are aligned and ready for measuring.

5.0 Test Procedures:

5.1 Remove the angle gage blocks and place the prism on the rotational stage, see Fig. 2.

5.2 Rotate and tilt the prism until the returned bright crosshairs center on the A autocollimator's reticle.

5.3 Use the D autocollimator's bright verticle line to read the 40°40' angle, see Fig. 4.

FIG. 1

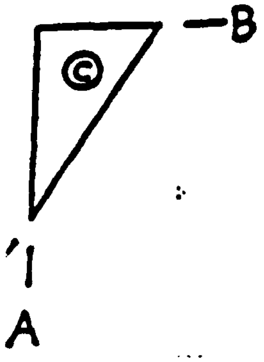


FIG. 2 Top View

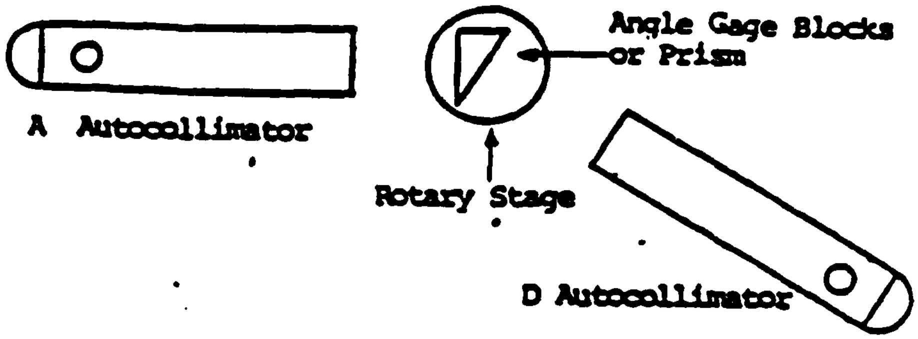


FIG. 3

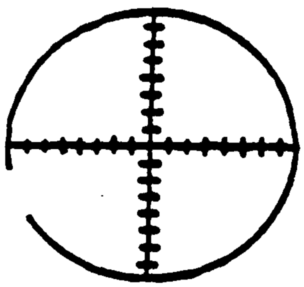
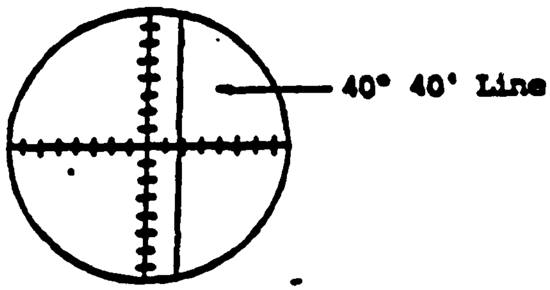


FIG. 4



RESULTS FOR S.I.P. #3

Sample Prism #	40°40' (spec= ± 1min)	
1	40°	40.5
2	"	41.0
3	"	41.0
4	"	41.0
5	"	43.3
6	"	41.3
7	"	40.5
8	"	39.2

S.I.P. NO: 4

Page: 1 of 4

Date: December 17, 1987

TITLE: TEST METHOD FOR PRISM SURFACE PERPENDICULARITY

1.0 Scope:

This is a procedure to measure perpendicularity between two polished prism faces, A and B.
I.L.S. Specification: < 2 arc minutes

2.0 Reference Documents:

I.L.S. Sketch #SK103382, see Fig. 1.

3.0 Test Equipment

Two Nikon Model #3035 Autocollimator; J.A. Noll Model #NPZAB-40 Positioning Device with Newport Model #470 Rotational Stage; Starrett-Weber Angle Gage Blocks (accuracy of ± 1 second)

4.0 Test Set-up:

4.1 Wring the angle gage blocks together to make an angle of 90° then place on the rotational stage.
4.2 Position the autocollimators in the horizontal plane perpendicular to sides A and B, label A autocollimator and B autocollimator, see Fig. 2.
4.3 Adjust the two axis' of both autocollimators until the returned bright crosshair center on the autocollimator's reticle (dark crosshair), see Fig. 3. Now the autocollimators are aligned and ready for measuring.

5.0 <u>Test Procedure</u>:

5.1 Remove the angle gage blocks and place the prism on the positioning device, see Fig. 2.

5.2 Viewing through the A autocollimator, rotate the prism until the bright vertical line centers on the reticle's dark vertical line.

5.3 Read the perpendicularity off the B autocollimator's X axis, see Fig. 4.

FIGURES FOR S.I.P. #4

FIG. 1

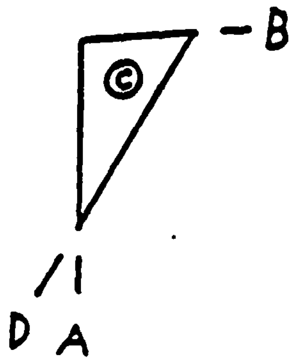


FIG. 2

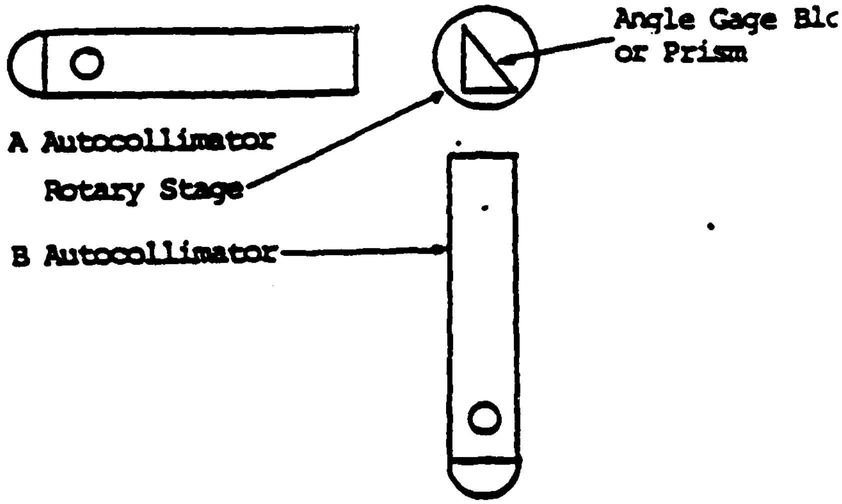


FIG. 3

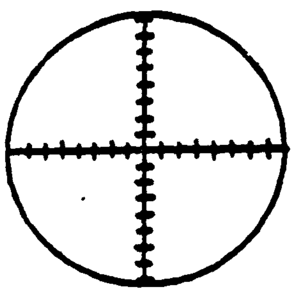
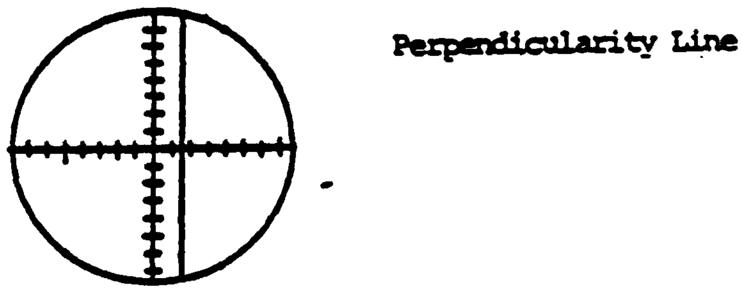


FIG. 4



RESULTS FOR S.I.P. #4

Sample Prism #	Deviation from Perpendicularity (spec ≤ 2 min)
1	4.7
2	1.0
3	- 1.8
4	- 0.5
5	0.5
6	- 2.0
7	0.6
8	0.0

TITLE: TEST METHOD FOR PRISM SURFACE PERPENDICULARITY

1.0 **Scope:**

This is a procedure to measure perpendicularity between a polished prism face and a ground prism face.
I.L.S. Specifications: < 2 arc minutes

2.0 **Reference Documents:**

I.L.S. Sketch #SK103382, see Fig. 1.

3.0 **Test Equipment:**

Two Nikon Model #3035 Autocollimators; J.A. Noll Model #NPZAB 40 Positioning Device with Newport Model #470 Rotational Stage, Optical Flat, Starrett-Weber Angle Gage Blocks (accuracy of ± 1 arc second)

4.0 **Test Set-up:**

4.1 Wring a single angle gage block to the optical flat and place on the rotational stage, see Fig. 2.

4.2 Position one autocollimator on the horizontal plane perpendicular to the angle gage block, label A/B/D Autocollimator see Fig. 3.

4.3 Adjust the two axis' of the A/B/D autocollimator until the returned bright crosshair centers on the autocollimator's reticle (dark crosshair), see Fig. 4.

4.4 Position the other autocollimator on the vertical plane above the angle gage block, Label C autocollimator, see Fig. 5.

4.5 Adjust the two axis' of the C autocollimator until the returned bright crosshair center on the autocollimator's reticle, see Fig. 4. Now the autocollimators are aligned and ready for measuring.

5.0 <u>Test Procedures:</u>

5.1 Remove the angle gage block from the optical flat.

5.2 Wring the prism's ground face C to the optical flat and place on the rotational stage, see Fig. 6.

5.3 Viewing through the A/B/D autocollimator, adjust the prism tilt and rotation until the bright crosshair returned from face A centers on the autocollimator's reticle.

5.4 Viewing through the C autocollimator, read perpendicularity from the Y axis, see Fig. 7.

5.5 Repeat step 5.4 for prism face B.

5.6 Repeat step 5.4 for prism face D.

FIGURES FOR S.I.P. #5

FIG. 1

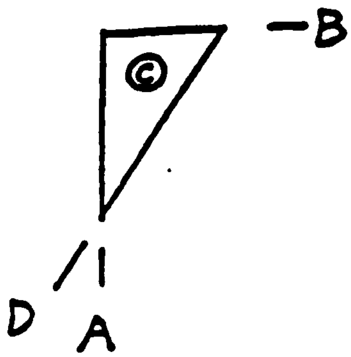


FIG. 2 Side View

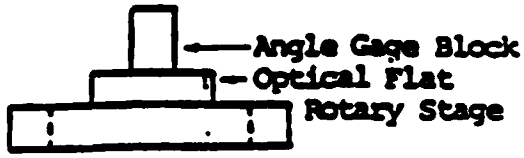


FIG. 3 Side View

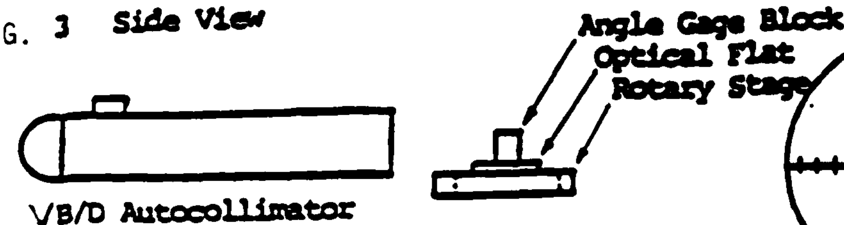


FIG. 4

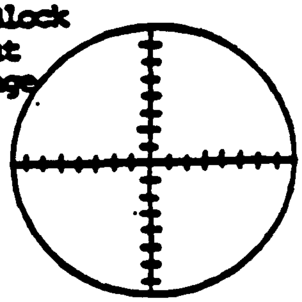


FIG. 5 Side View

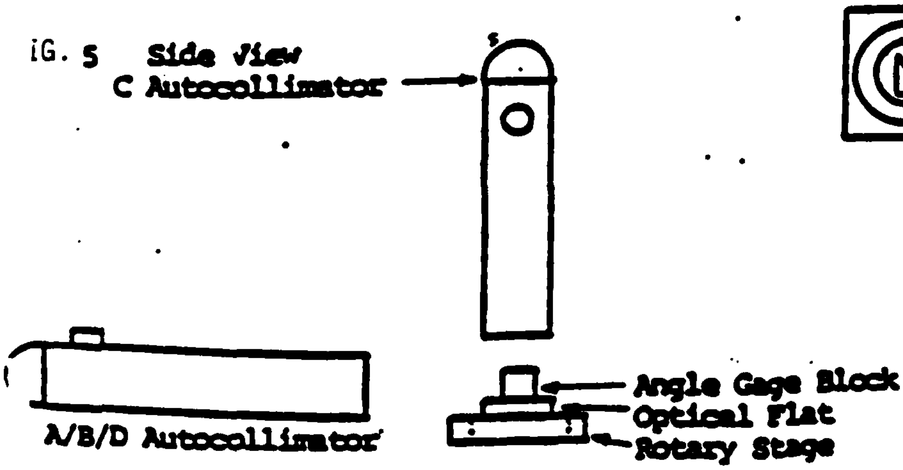


FIG. 6 Top View

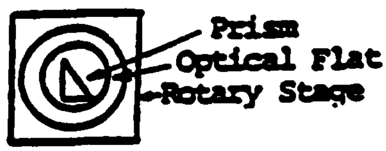
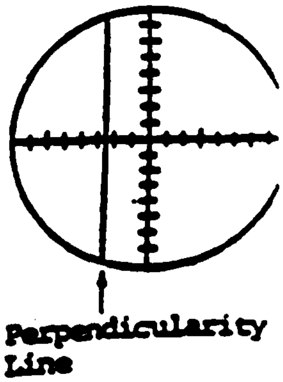


FIG. 7



RESULTS FOR S.I.P. #5

L.L.S. SPEC < 2 min

Sample Prism #	Deviation from Perpendicularity A to C	B to C	D to C
1	1.4	0.3	0.5
2	1.0	2.4	1.0
3	0.2	1.5	1.0
4	2.5	- 1.2	1.0
5	0.1	- 0.7	3.3
6	1.0	0.8	1.3
7	2.0	1.0	0.5
8	- 0.7	- 2.0	-0.8

S.I.P. NO: 6

Page: 1 of 3

Date: December 17,1987

TITLE: TEST METHOD FOR MEASURING PAD THICKNESS

1.0 **SCOPE:**

This is a procedure to measure pad thickness on a prism hypotenuse surface.

2.0 **REFERENCE DOCUMENT:**

Sloan Dektak IIA Instruction Manual

3.0 **Test Equipment:**

Sloan Dektak Model # IIA surface profile measuring system, prism holding fixture and calibration standard.

4.0 **Test Set-up:**

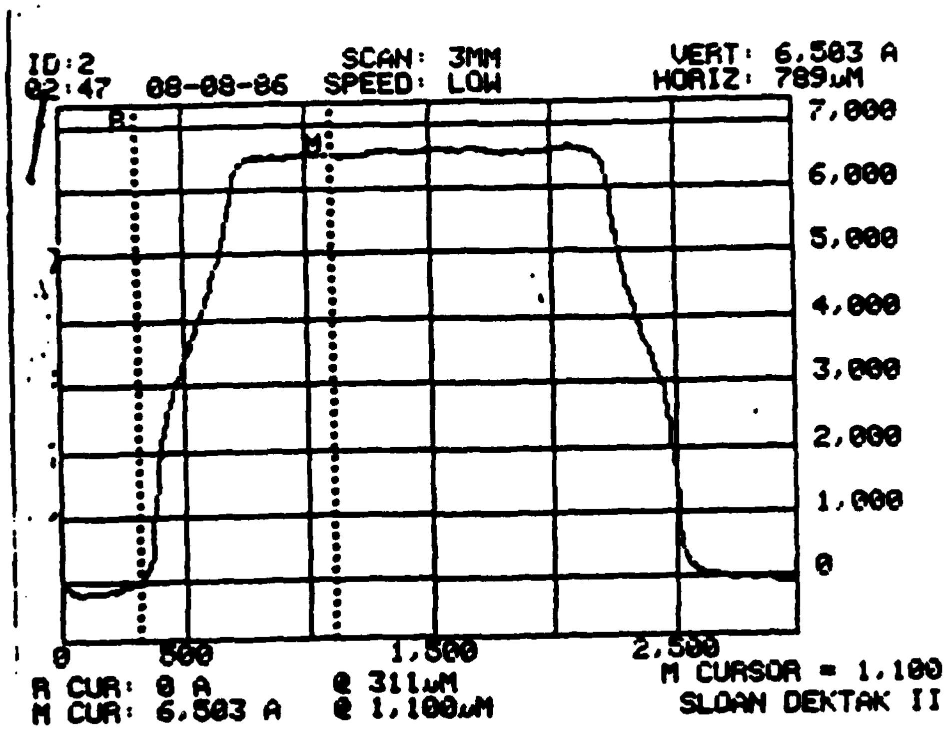
4.1 Turn Dektak IIA unit on.
4.2 Wait 20 minutes for warm-up.
4.3 Select program by entering program number.
4.4 Enter I.D. number.
4.5 Set scan length to "2MM". Press "ENTER".
4.6 Set scan speed to "MEDIUM". Press "ENTER".
4.7 Set range to "AUTO". Press "ENTER".
4.8 Set profile to "⌐⊔⌐" setting. Press "ENTER".
4.9 Set auto leveling to "YES", "0 to 2MM". Press "ENTER".
4.10 Set R cursor to "0MM". Press "ENTER".
4.11 Set M cursor to "2MM". Press "ENTER".
4.12 Position calibration standard on the rotary stage under stylus.
4.13 Press "STYLUS".
4.14 Press "SCAN".
4.15 Check readout of calibration standard. (8700 KA). If acceptable, proceed with test procedure.

5.0 <u>Test Procedure</u>

5.1 Replace calibration standard with prism to be mounted in prism holding fixture.

5.2 Repeat steps # 4.13 & 4.14.

5.3 Attached is a typical scan of deposited T A 2 0 5 on a prism.



THICKNESS OF TA_2O_5 PAD

TITLE: **TEST PROCEDURE FOR POLARIZING CUBES**

1.0 **Scope:**

This is a procedure to test polarizing prisms for Tp and contrast ratio.

2.0 **Reference Documents:**

LLS Test Procedure

3.0 **Test Equipment:**

Neslab Model #HX-50 Refrigerating Recirculator, Spectra-Physics Model #102-4 HeNe Laser, CVI Model #C-90 Nd:YAG Laser, Proteus Industries Model #100C Fluid Flow Switch, Laser Precision Model #CTX-532 Chopper, Newport Model #900 Collimator, Karl Lambrecht Model #MGLA-15-V1064 Glan Laser Prism Polarizer, 2 Karl Lambrecht Model #MW2A-15-10-V1064 Wollaston Prism Polarizers, Tektronix Model #2445 Oscilloscope, Laser Precision Model #RK-5200 Power Ratiometer, 3 Laser Precison Model RKP-545RX detector probes, Airtron Dichroic Mirror (HR @ 1.06 nm @ 45°/BBAR VIS), 1/16" aperture, Airtron Part #A-12-12 Half-Wave Plate @ 1.06 nm, a microscope slide, 2 first surface metal mirrors, Airtron Prism Assembly/Test Fixture, Coherent Model #201 Power Meter and Pyroelectric Detector, Hamamatsu Quadrant Detector with Simpson Digital Readout Display, United Detector TEhcnology Model #61 Optometer with Silicon Detector, Standard Polarizer, and FJW Industries IR Finder Viewer.

4.0 **Test Setup:**

4.1 Use Coherent power meter and pyroelectric detector.
4.2 Adjust Nd:YAG laser mirrors for maximum output. Adjust tilt of Nd:YAG laser so beam is parallel to table surface.
4.3 Position dichroic mirror so it is centered to reflect the Nd:YAG beam at a 90° angle.
4.4 Block Nd:YAG beam.
4.5 Place choppoer between Nd:YAG laser and dichroic mirror.
4.6 Turn chopper on.
4.7 Position and adjust HeNe laser so beam passes through center of dichroic mirror.

4.8 Align HeNe beam to Nd:YAG beam using quadrant detector and the following procedure:
   a) Block HeNe and Nd:YAG beams
   b) Turn on quadrant detector with digital displays.
   c) Place quadrant detector approximately 6 inches after dichroic mirror.
   d) Unblock Nd:YAG beam.
   e) Adjust X and Y axis of quadrant detector until both X and Y digital displays read "0.000".
   f) Block Nd:YAG beam
   g) Unblock HeNe beam
   h) Adjust X and Y axis of HeNe laser mount until both X and Y digital displays read "0.00".
   i) Block HeNe beam.
   j) Move quadrant detector approximately 3 feet from dichroic mirror.
   k) Repeat steps d through g, then proceed to step l.
   l) Adjust tilt and theta of HeNe laser mount until both X and Y digital displays read "0.00".
   m) Block HeNe beam.
   n) Repeat steps c through m until the HeNe beam is aligned with the Nd:YAG beam.

4.9 Block Nd:YAG beam
4.10 Unblock HeNe beam
4.11 Adjust position tilt and theta of first metal mirror to reflect beam through the center of the collimator's lenses
4.12 Position 1/16" aperture near center of collimated beam
4.13 Adjust 1/16" aperture for maximum output of Nd:YAG and HeNe beam (use United Detector Technology power meter with silicon detector.)
4.14 Adjust tilt of second metal mirror to reflect the beams parallel to the table surface.
4.15 Adjust the height of test chambers to pass beam through the centers of the entrance and exit polairzer faces.
4.16 Adjust rotation of second metal mirror to pass beam through the centers of the entrance and exit polarizer faces.
4.17 Rotate the exit Wollaston prism in its mount until the two HeNe exit beams are at the same height using an aperture to check height.
4.18 Center detector A on one of the two exit beams.
4.19 Center detector B on the other beam.
4.20 Turn on power ratiometer.
4.21 Set averaging time to medium.
4.22 Set each detector range to the 10-2 scale.
4.23 Block HeNe beam.
4.24 Unblock Nd:YAG beam.
4.25 Plug ratiometer mixer output into oscilloscope.
4.26 Set oscilloscope "Volts/Div" to .5V.
4.27 Set oscilloscope "Sec/Div" to 10ms.
4.28 Turn ratiometer "Phase Adjust" knob until curves on oscilloscope form wave, see Fig. #1.

4.29 Re-adjust A and C mounts for maximum output
4.30 Set power ratiometer to "C/A" (ratio) mode
4.31 Rotate half-wave plate until a ratio of 1.000 ± .005 is achieved
4.32 Lock half-wave plate into position
4.33 Place the prism assembly/test fixture into the test chamber with the standard polarizer inserted
4.34 Center the Nd:YAG beam on the standard polarizer
4.35 Block the Nd:YAG beam
4.36 Unblock the HeNe beam
4.37 Adjust tilt and roll of test fixture using retroreflection on aperture to adjust tilt and another aperture to adjust roll of reflected S polarization.

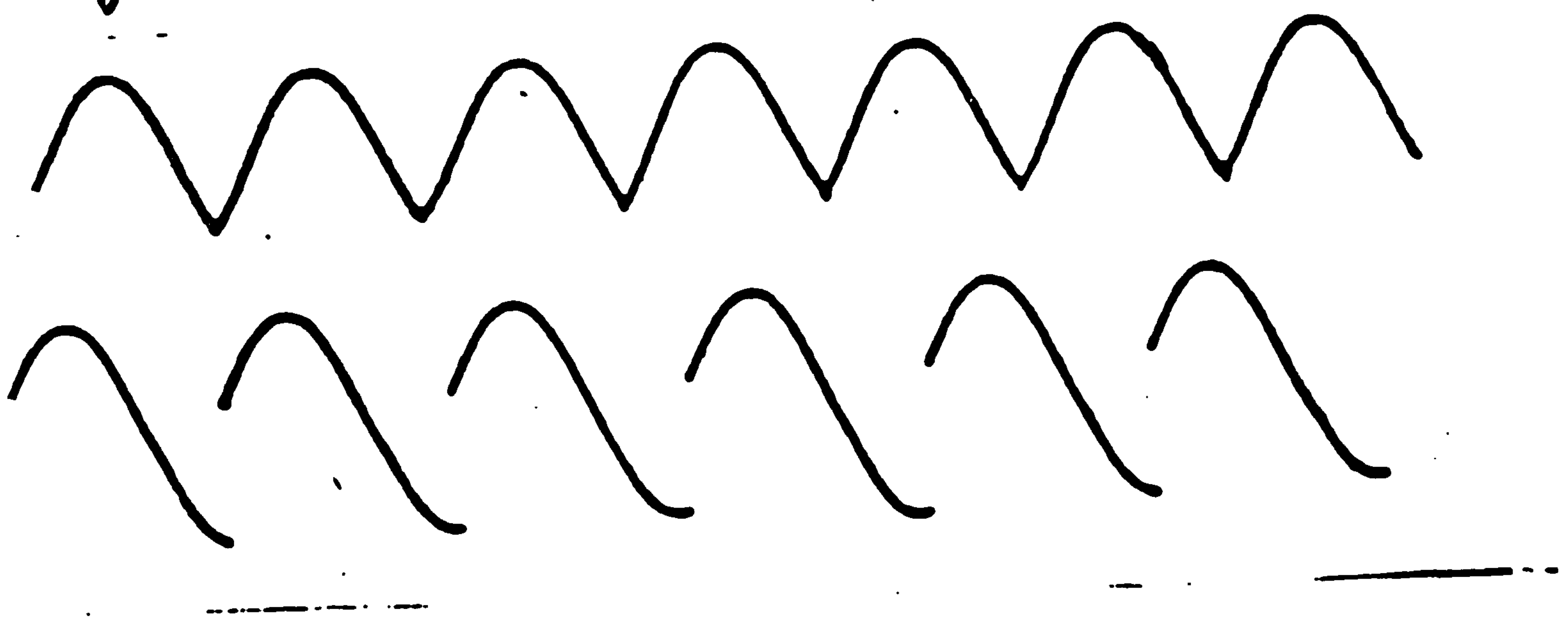
5.0 <u>Test Proceure:</u>

5.1 Unblock the Nd:YAG beam
5.2 Adjust the detector C range to 10^{-5} scale
5.3 Write down the peak ratio reading
5.4 Block the Nd:YAG beam
5.5 Record ratio as contrast ratio
5.6 Unplug detector C and plug in detector B
5.7 Align detector B to reflected beam from microscope slide
5.8 Unblock Nd:YAG beam
5.9 Adjust detector B scale to 10^{-2}
5.10 Write down the peak reading measured
5.11 Block Nd:YAG beam
5.12 Calculate and record Tp (%) by:

$$\left[\frac{\text{(Reading without Polarizer)}}{\text{(Reading with Polarizer)}}\right] \times 100 = \text{Tp\%}$$

If it is off lag more than ± 3%, check alignment and setup per section 4. If it is within ± 3%, continue to 5.13.
5.13 Remove standard polarizer and replace it with the prism to be tested.
5.14 Unplug detector B and plug in detector C.
5.15 Repeat steps 5.1 through 5.14.

Fig #1 - Sync. Output on Oscilloscope.



Date: December 17, 1987

TITLE: TEST METHOD FOR SPECTROPHOTOMETRIC ANALYSIS OF ANTI-REFLECTION COATINGS. Surfaces A + C Long Leg Air @ Normal and Surfaces B.E. Short Leg Air @ 13°

1.0 Scope:

This is a procedure to evaluate Anti-Reflection Coatings using a Spectrophotometer.

2.0 Reference Documents

Varian/Cary Model 17D Spectrophotometer System Owner's Manual.

3.0 Test Equipment:

Varian Cary Model 17D Spectrophotometer with Specular Reflectance Attachment. Mounting Carriage. fixture. aperature. uncoated quartz standard and coating run witness sample.

4.0 Test Set-Up

4.1. Read Varian Model 17D Operating instructions and get familiar with panel controls.

4.2. Balance the source/detector system using the following procedure:

a) Determine center wavelength of measurement. Select multipot thumwheel closest to center wavelength. For an Anti-Reflection coating @ 1064 nm the center wavelength would be 1064 n.. The closest multipot thumwheel would be 1050 nm.
b) Turn "Pen" switch off.
c) Turn "Slit" switch off.

d) Open sample chamber.
e) Insert specular refectance carriage in sample chamber and align guide pins into base.
f) Place uncoated quartz standard on specular reflectance attachment.
g) Close sample chamber.
h) Set "Pen Lift" switch to Up position.
i) Set "Platen" switch to Free position.
j) Align chart pen to heavy line on chart paper using platen and pen down button.
k) Turn "Auto Stop" switch off.
l) Turn "Slit" switch on
m) Pull "Slit Height" knob out.
n) Scan and calibrate using scan pen balance duodial. blind aperture and following procedure:

    1) Activate "Scan" and adjust to 1050 n..
    2) Adjust 1050 nm multipot thumbwheel until display panel reads "0337"
    3) Activate "Scan" and adjust to 900 nm.
    4) Adjust 900 nm multipot thumbwheel until display panel reads 0340.
    5) Repeat steps #1 & 2.
    6) Activate "Scan" and adjust to 1200 n..
    7) Adjust 1200 nm multipot thumbwheel until display panel reads "0335"
    8) Repeat steps #3 & 4.
    9) Repeat steps #1 & 2.
    10) Repeat steps #6 & 7.

0) Turn "Pen" switch on.
p) Turn "Paten" switch to "engaged"
q) Turn "Pen Lift" switch to "Auto".
r) Set "Scan" to "-".
s) Turn "Auto Stop" to off.
t) Once scan is below 1000 nm. set "Auto Stop" switch on.
u) Turn "Pen" switch off.
v) Set "Scan" to "+".
w) Turn "Auto Stop" switch off.
x) Once scan is above 1100 nm. set "Auto Stop" switch on.

4.3 Set Baseline using the following procedures

a) Turn "Pen" switch off.
b) Turn "Slit" switch off.
c) Open sample chamber and remove uncoated quartz standard.
d) Turn "Pen" switch on.
e) Turn "Slit" switch on.
f) Set "Scan" to "-"
g) Turn "nm/sec" to 5
h) Turn "Auto Stop" switch off.
i) Once scan is below 1000 nm. turn "Auto Stop" switch on.
j) Set "Scan" to "+"
k) Turn "Auto Stop" switch off.
l) Once scan is above 1100 nm. turn "Auto Stop" switch on.

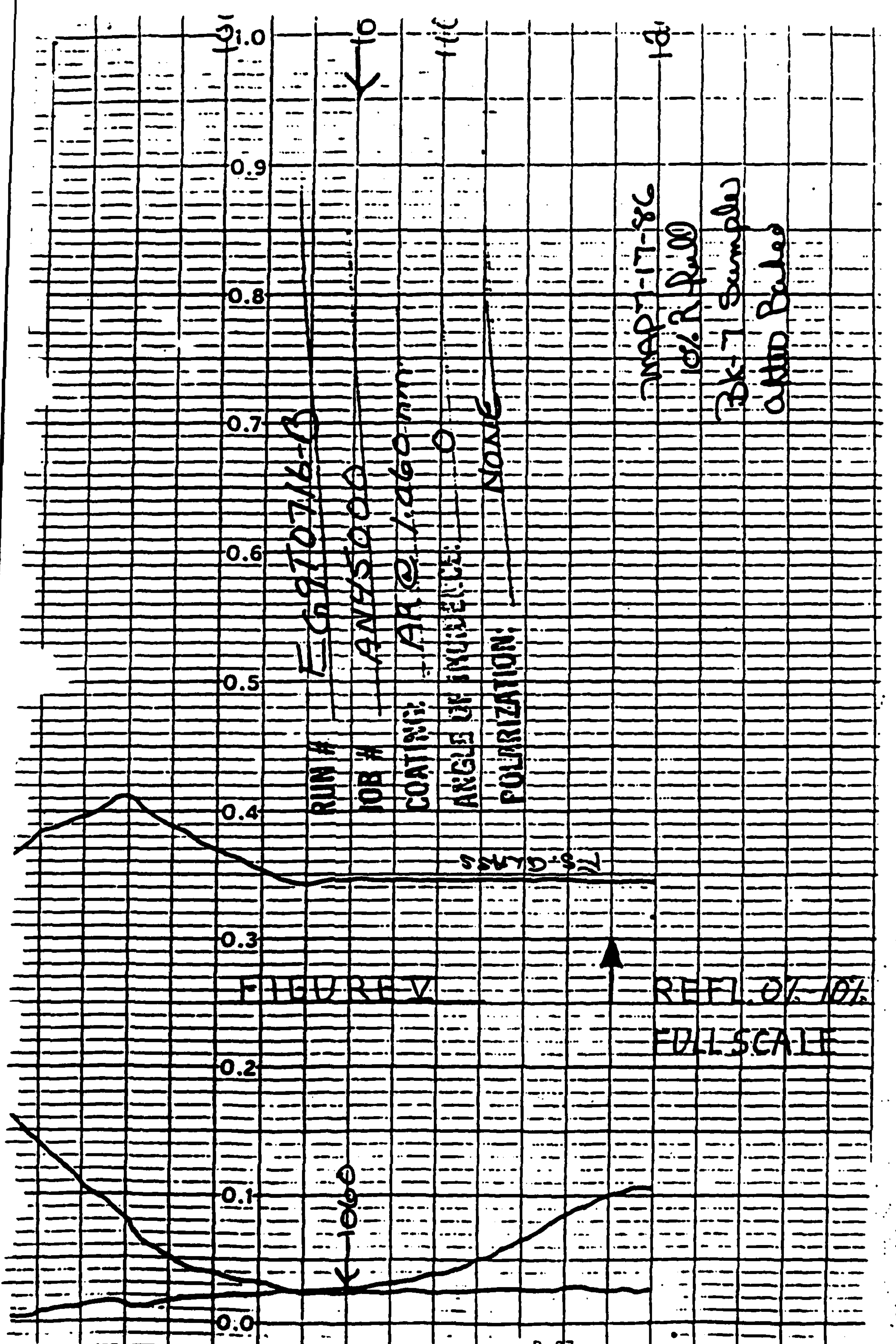
5.0 <u>Test Procedure</u>

a) Turn "Pen" switch off.
b) Turn "Slit" switch off.
c) Open sample chamber and insert coating run witness sample.
d) Set "Scan" to "-".
e) Turn "Pen" switch on.
f) Turn "Auto Stop" switch off.
g) Once scan is below 1900 nm. turn "Auto Stop" on.
h) Turn "Platen" switch to "free"
k) Lable curve.

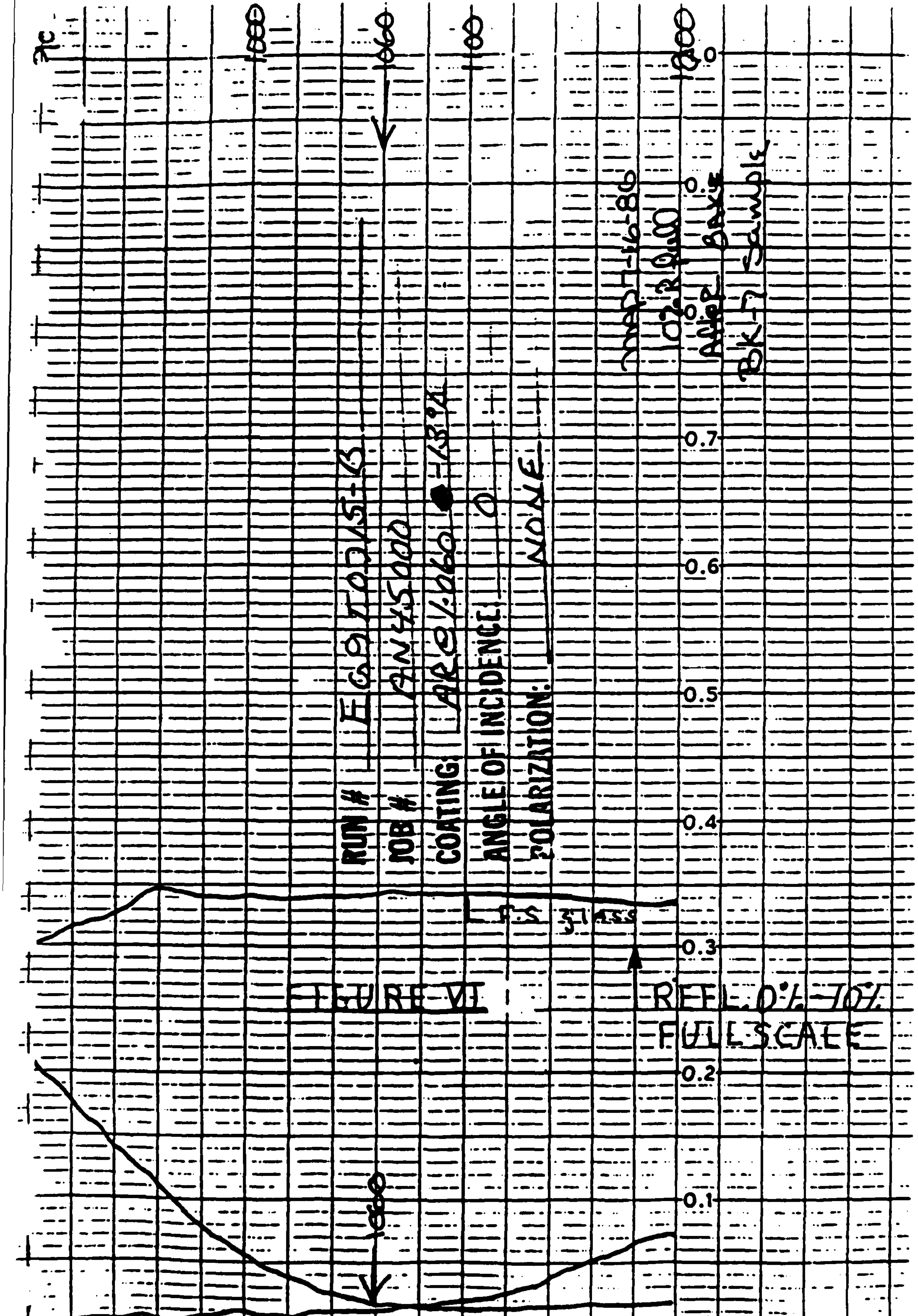
6.0 Spectral Curves

6.1 Attached Figure V is a typical spectral curve for the A.R coating at normal angle of incidence. The back surface of the witness piece has been ground and blackened to eliminate 2nd surface reflection.

6.2 Attached Figure VI is a typical spectral curve for the A.R coating @ 13° angle. This curve was run @ normal angle of incidence.



RUN # EG970716-B
JOB # AN45000
COATING: AR @ 1060 nm
ANGLE OF INCIDENCE: 0
POLARIZATION: NONE
MAR-17-86
10% R Full
Bk-7 Samples
after Bake
FIGURE V
REFL. 0% 10%
FULLSCALE
1060
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


RUN #
JOB #
COATING:
ANGLE OF INCIDENCE:
POLARIZATION:
NONE
After Bake
BK-7 Sample
FIGURE VI
REFL 0%-10%
FULLSCALE
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1.0

TITLE: METHOD FOR SPECTROPHOTOMETRIC ANALYSTS OF POLARIZING COATINGS

1.0 Scope:

This is a procedure to evaluate polarizing coatings using a spectrophotometer.

2.0 Reference Documents:

Varian/Cary model 17 D Spectrophotometer System Owner's Manual. Operating Procedures Section #5.

3.0 Test Equipment

Varian/Cary Model 17D Spectrophotometer. mounting carriage. mounting fixture with aperature and coating run witness sample.

4.0 Test Set-Up:

4.1 Read Varian/Cary model 17D operating instructions and get familiar with panel controls.

4.2 Balance the source/detector system using the following procedure:

a) Determine center wavelength of measurement. Select multipot thumbwheel closest to center wavelength. For a polarizing coating at 1465 nm the center wavelength would be 1465 nm. The closest multipot thumbwheel would be 1500 nm.
b) Turn "Pen" switch off.
c) Turn "Slit" switch off.
d) Open sample chamber.
e) Insert fixture with aperature and carriage in sample chamber and align guide pins into base.

f) Close sample chamber.
g) Set "Pen Lift" switch to "Up" position.
h) Set "Platen" switch to "Free" position.
i) Align chart pen to heavy line on chart paper using platen and pen down button.
j) Turn "Auto Stop" switch off.
k) Turn "Slit" switch off.
l) Push "Slit Height" knob in.
m) Scan and calibrate using scan drive. pen balance duodial. blind aperature and the following procedure.

    1) Activate "Scan" and adjust to 1500 nm.
    2) Adjust 1500 n. multipot thumwheel until display panel reads "1.000".
    3) Turn "Scan" to "-" and adjust to 1350 nm.
    4) Adjust 1350 nm multipot thumwheel until display panel reads "1.000"
    5) Repeat steps #1 and 2.
    6) Turn "Scan" to "+" and adjust to 1650nm
    7) Adjust 1650 n. multipot thumbwheel until display panel reads "1.000".
    8) Repeat steps #3 and 4.
    9) Repeat steps #1 and 2.
    10) Repeat steps #6 and 7.

n) Turn "Pen" switch on
O) Turn "Platen" switch to "engaged"
p) Turn "Pen Lift" switch to "auto".
q) Set "Scan" to "-".
r) Once scan reaches 1350 nm. turn "Scan" to "Off".
s) Turn "Pen" switch off.
t) Set "Scan" to "+".
u) Once scan reaches 1650 n.. turn "Scan" to "Off".

4.3 Set Baseline using the following procedure:

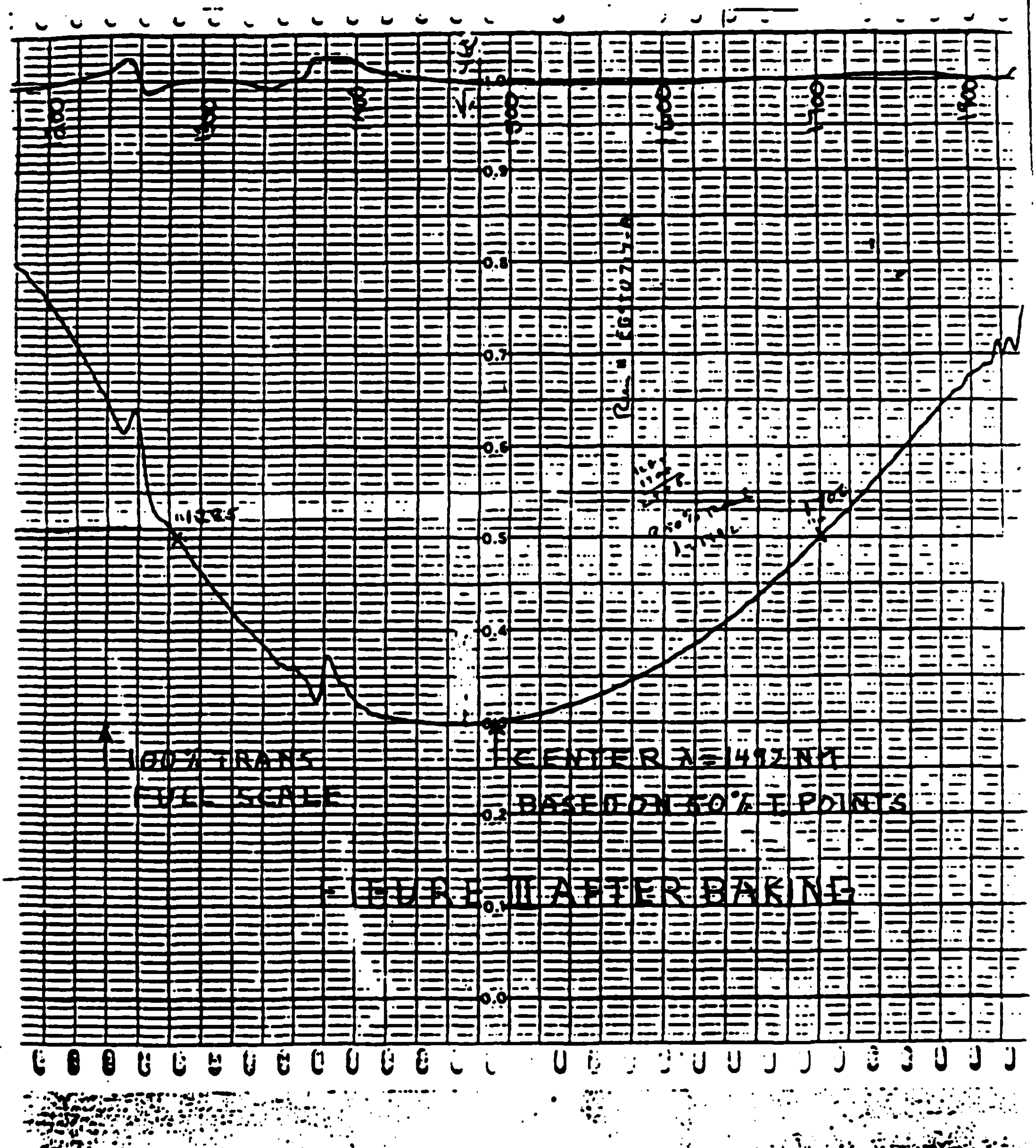
a) Turn "Pen" switch on.
b) Turn "Slit" switch on.
c) Set "Scan" to "-".
d) Once scan reached 1350. turn "Scan" to "Off".
e) Set "Scan" to "+".
f) Once scan reaches 1650. turn "Scan" to "Off".

5.0 <u>Test Procedure</u>:

a) Turn "Pen" switch off.
b) Turn "Slit" switch off.
c) Open sample chamber and insert coating witness.
d) Turn "Pen" switch on.
e) Turn "Slit" switch on.
f) Set "Scan" to "-".
g) Once scan reaches 1350. turn "Scan" to "Off".
h) Turn "Platen" switch to "Free"
i) Label curve.

6.0 Spectral Curve

6.1 Attached Figure III is a typical spectral curve of the polarization coating. Based on the results of this curve. the pad thickness is calculated. Refer to S.P.P.NO. 1005


100% TRANS
FULL SCALE
CENTER λ=1492NM
BASED ON 50% T POINTS
FIGURE III AFTER BAKING

TITLE: **TEST METHOD FOR PRISM FACE ANGLE MEASUREMENTS**

1.0 **SCOPE:**

This is an alternate procedure to measure perpendicularity between prism faces A, B and C, angle between A and D, and pyramidality, in a single set-up. I.L.S. Specifications: Angle Between A and D: $40^\circ 40' \pm 1'$, Pyramidal Error less than 30", A, B and C perpendicular to within 2 arc minutes.

2.0 **Reference Documents:**

I.L.S. Sketch #SK103382

3.0 **Test Equipment:**

Nikon Model #3035 Autocollimator, Leitz Optical Master Dividing Head Starret Webber 90° gage block (accuracy of $\pm$ 1 arc second).

4.0 **Test Set-Up**

4.1 Wring the 90° gage block to the Dividing Head surface plate.

4.2 Position the autocollimator in the horizontal plane of the Dividing Head surface plate(perpendicular to the 90° gage block).

4.3 Adjust the two axis' of the autocollimator until the returned bright crosshairs center on the autocollimator's reticle (dark crosshairs). Now the autocollimator is aligned and ready for measuring.

5.0 **Test Procedure:**

5.1 Remove the 90° gage block and wring the ground C side of the prism onto the rotational stage, see Fig. # 1.

5.2 Rotate the prism until the returned bright vertical line from surface B centers on the autocollimator's horizontal reticle scale.

5.3 Use the returned bright horizontal line to read the error in perpendicularity between sides B and C. See figure #2.

5.4 Record the Dividing Head angle by reading the master circle scale as described in section 4.2 of the Optical Master Dividing Head instruction manual.

5.5 Rotate Dividing Head until the returned bright vertical line from surface A centers on the autocollimator's horizontal reticle scale.

5.6 Use the returned bright horizontal line to read the error in perpendicularity between sides A and C.

5.7 Record the Dividing Head angle by reading the master circle scale.

5.8 Subtract the angle recorded in 5.7 from that recorded in 5.4 to obtain the angle between sides A and B. Subtract 90° from this angle to obtain the error in perpendicularity between sides A and B.

5.9 Rotate the Dividing Head until the very bright porro reflection becomes strong (this will occur before encountering the D surface reflection).

6.0 Read the pyramidal error from the vertical reticle scale (Separation of the bright horizontal line may be minimal). See Figure #3.

6.1 Continue rotating the head until the fainter reflection from surface D is centered on the autocollimator's horizontal reticle scale.

6.2 Record the Dividing Head angle.

6.3 Subtract the angle recorded in 5.7 from the sum of 180° plus the angle recorded in 6.2 to obtain the angle between A and D (ie:40° 40').

FIG. #1 - Top Veiw

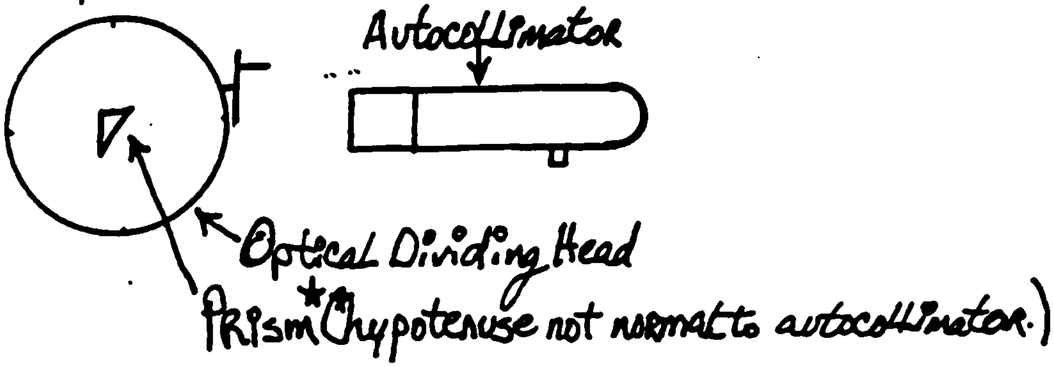


FIG. #2 - Autocollimator Veiw - Perpendicularity Error

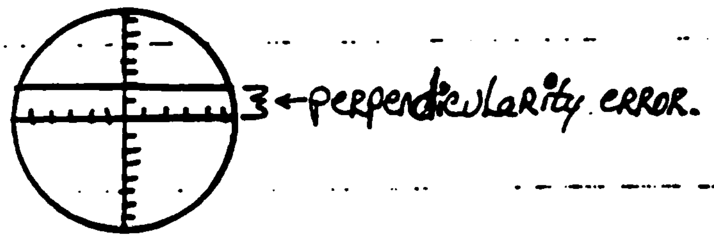
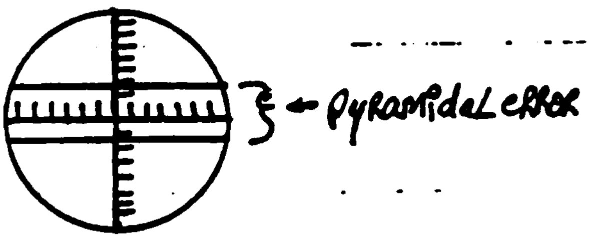


FIG. #3 - Autocollimator Veiw - Pyramidal Error



TITLE: TEST METHOD FOR POLARIZER ASSEMBLY OUTPUT BEAM DEVIATION

SCOPE:

THIS IS A PROCEDURE TO MEASURE TRANSMITTED AND REFLECTED BEAM DEVIATION FOR AN ASSEMBLED POLARIZER CUBE. SPECIFICATION: TRANSMITTED BEAM DEVIATION TO BE LESS THAN 2 ARC MINUTES FROM THE INPUT BEAM. REFLECTED BEAM DEVIATION TO BE LESS THAN 4 ARC MINUTES FROM A PLANE CONTAINING THE NORMALS OF SURFACES A AND B WHEN THE INPUT BEAM IS NORMAL TO ENTRANCE SURFACE A.

.0 REFERENCE DOCUMENTS:

L.L.S. LASER POLARIZER SPECIFICATION, REV. G ("LPS, REV. G")
L.L.S. SKETCH SK 103382

.0 TEST EQUIPMENT:

3.1 TWO AUTOCOLLIMATORS, NIKON MODEL 6D OR EQUIVALENT.
3.2 2-AXIS TILT AND ROTATION STAGE.
3.3 MIRROR ON MIRROR MOUNT. (2 AXIS)
3.4 SURFACE PLATE WITH SUFFICIENT AREA FOR 3.1, 3.2 AND 3.3.
3.5 REFERENCE POLARIZER PRISM PER LLS-SK 103382 LESS THAN 2 ARC SECOND PYRAMIDAL ERROR AND 40° 40′ ERROR.

.0 TEST SET-UP:

4.1 USING THE REFERENCE PRISM OF 3.5 POSITION EQUIPMENT AS SHOWN IN FIGURE 1. ADUST REFERENCE PRISM AND TWO AUTOCOLLIMATORS SO THAT THE RETURN IMAGES FROM SURFACE A AND B OF REFERENCE PRISM ARE ALIGNED WITH THE RETICLE CROSSHAIRS.

4.2 ADJUST THE MIRROR MOUNT OF 3.3 TO RETURN AUTOCOLLIMATOR #1 IMAGE (REFLECTED BY TIR OFF THE HYPOTENUSE OF THE REFERENCE PRISM) ONTO THE RETICLE CROSSHAIR.

4.3 LOCK AUTOCOLLIMATORS AND MIRROR INTO THESE POSITIONS AND REMOVE REFERENCE PRISM.
IN ALL SUBSEQUENT TEST PROCEDURES DO NOT ADJUST AUTOCOLLIMATORS OR MIRROR; ADJUST ONLY 2-AXIS TILT AND ROTATION STAGE.

5.0 TEST PROCEDURE:

5.1 POSITION ASSEMBLED POLARIZER CUBE TO BE TESTED ("UNIT UNDER TEST" OR "UUT") ON 2-AXIS TILT AND ROTATION STAGE. (SEE FIGURE 1). ADJUST THE STAGE TO ALIGN THE RETURN IMAGE FROM SURFACE A WITH THE RETICLE CROSSHAIR IN AUTOCOLLIMATOR #1.

5.2 ADJUST THE 2-AXIS TILT AND ROTATION STAGE (USING ONLY THE AXIS THAT MOVES THE RETURN IMAGE FROM SURFACE B IN A VERTICLE DIRECTION IN AUTOCOLLIMATOR #2) TOALIGN THE RETURN IMAGE FROM SURFACE B WITH THE RETICLE CROSSHAIR IN AUTOCOLLIMATOR #2. SOME MISS ALIGNMENT IN THE HORIZONTAL DIRECTION (IE: SEPARATION BETWEEN VERTICLE LINES OF THE RETURN IMAGE AND THE RETICLE CROSSHAIR) WILL BE ALLOWABLE. ACHIEVING ALIGNMENT IN THE VERTICLE DIRECTION IN AUTOCOLLIMATOR #2 SHOULD NOT AFFECT ALIGNMENT IN EITHER DIRECTION IN AUTOCOLLIMATOR #1.

5.3 MEASURE THE SEPARATION BETWEEN THE RETURN IMAGES OF THE MIRROR AND SURFACE A IN AUTOCOLLIMATOR #1 IN THE VERTICLE DIRECTION (IE: SEPARATION BETWEEN THE HORIZONTAL LINES OF IMAGES.) SEE FIGURE 2. RECORD THIS AS THE REFLECTED BEAM DEVIATION, R. (SEPARATION IN THE HORIZONTAL DIRECTION, DUE TO 40° 40' ANGLE ERROR CAN BE IGNORED.)

5.4 ALSO VISIBLE IN AUTOCOLLIMATOR #1 IS THE MUCH FAINTER RETURN IMAGE OF THE SURFACE C (SEE FIGURE 2). MEASURE THE SEPARATION, X, BETWEEN THE RETURN IMAGESOF A AND C IN THE HORIZONTAL DIRECTION (IE: SEPARATION BETWEEN THE VERTICLE LINES OF THE IMAGES.) MEASURE THE SEPARATION, Y, BETWEEN THE RETURN IMAGES OF A AND C IN THE VERTICLE DIRECTION (IE: SEPARATION BETWEEN THE HORIZONTAL LINES OF THE IMAGES.)

5.5 CALCULATE THE POLAR SEPARATION OF THE IMAGES BY THE FOLLOWING FORMULA:

$$\Theta = \sqrt{X^2 + Y^2}$$

5.6 APPLY THE FOLLOWING FORMULA (DERIVATION IS ATTACHED AS AN APPENDIX TO THIS S.I.P.) TO OBTAIN THE TRANSMITTED BEAM DEVIATION, :

$$\delta = \frac{1}{2}(n' - 1) \arcsin\left(\frac{\sin\Theta}{n'}\right)$$

where $n' = 1.517$ for BK-7 @ 547 nm.

RECORD THIS AS TRANSMITTED BEAM DEVIATION.

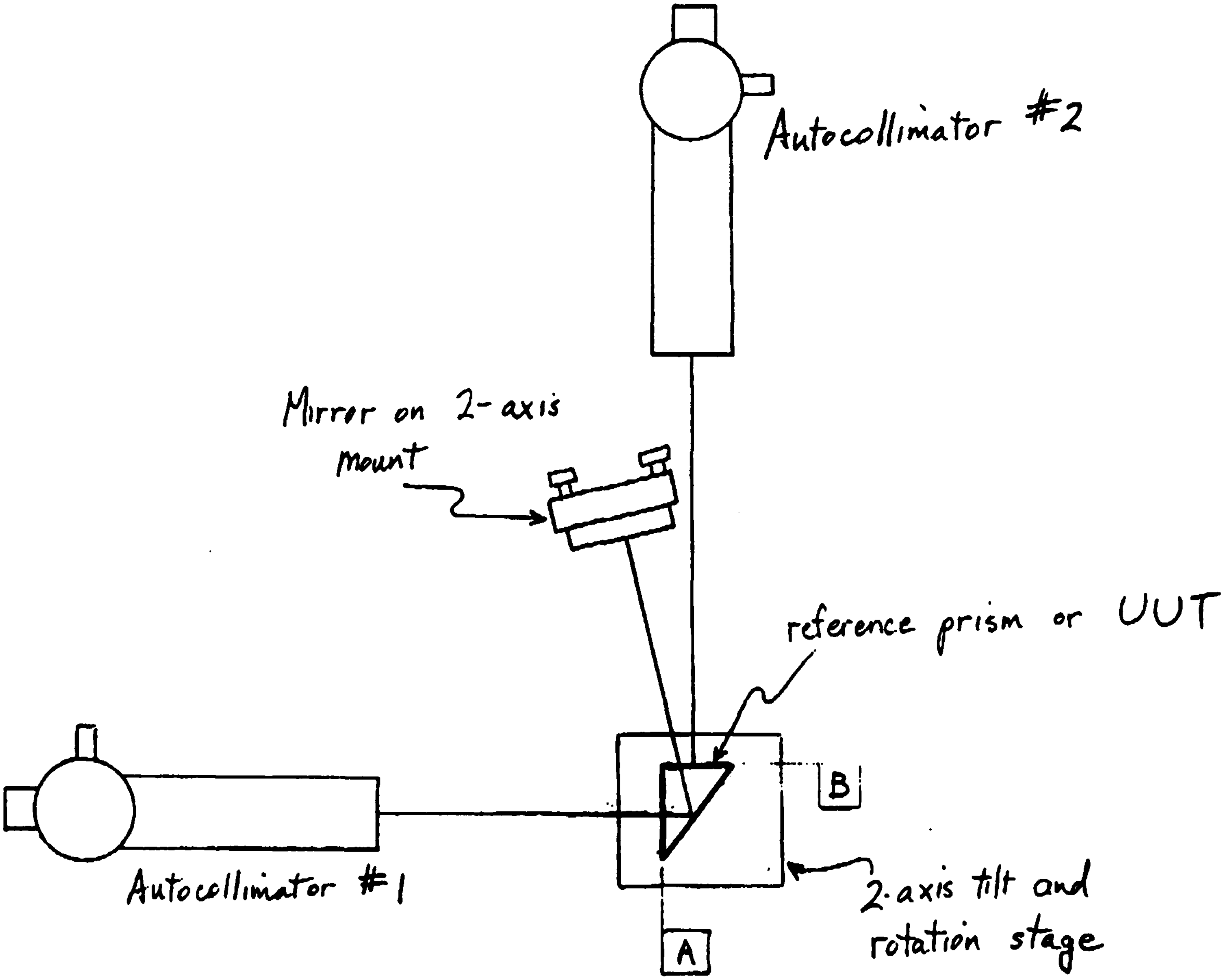
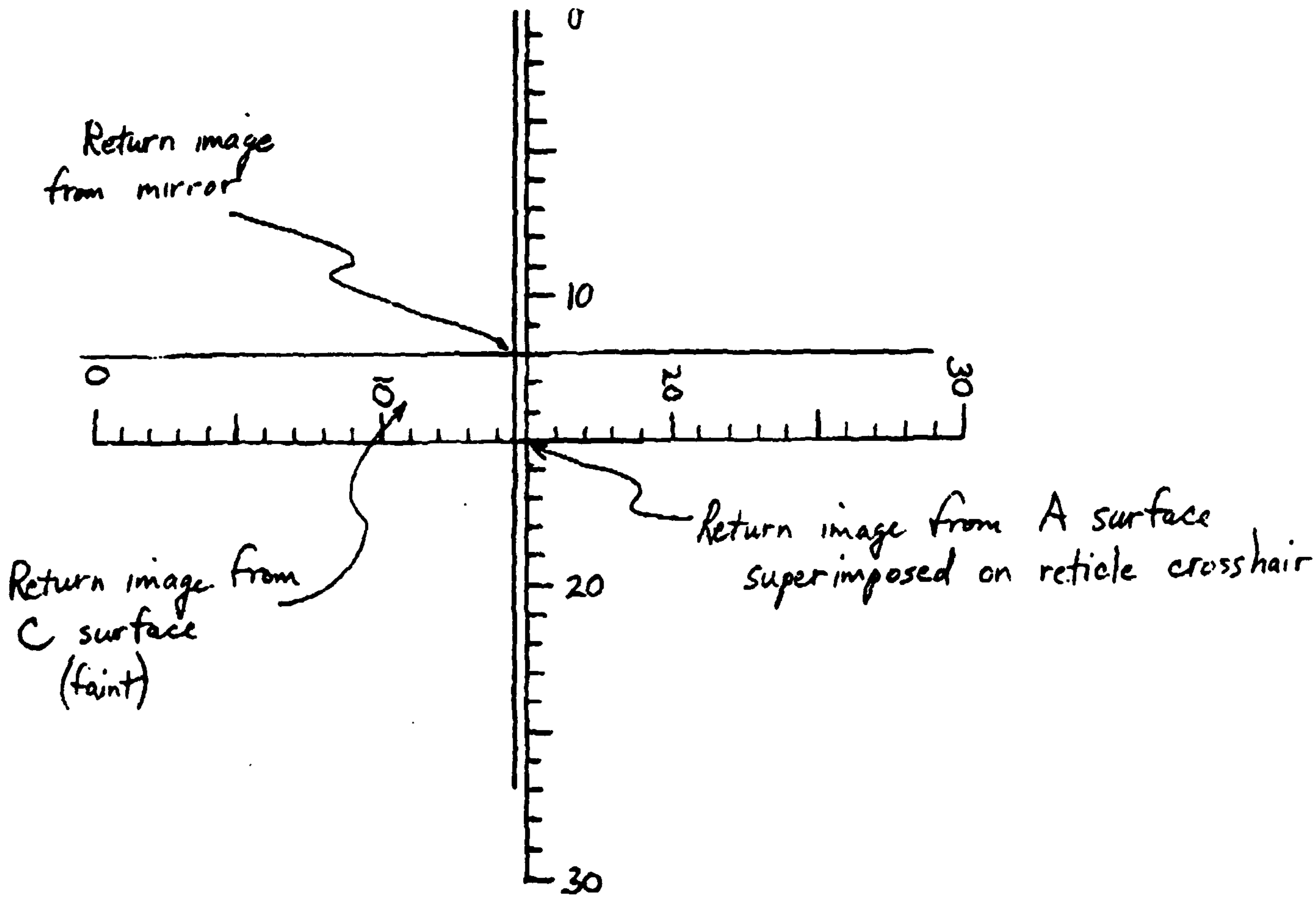

Autocollimator #2
Mirror on 2-axis mount
reference prism or UUT
B
Autocollimator #1
2-axis tilt and rotation stage
A

FIGURE 1.



In this example: $R = 3.0'$ (reflected beam deviation)

$$\left.\begin{array}{l} X = 4.0' \\ Y = 1.5' \end{array}\right\} \quad \Theta = \sqrt{4.0^2 + 1.5^2} \doteq 4.27'$$

$$\delta = 0.73' \text{ (transmitted beam deviation)}$$

FIGURE 2.

M.P.P. NO: 1

Page: 1 of 2

Date: December 17, 1987

TITLE: CLEANING PROCEDURE FOR PRISM COATING

1.0 **SCOPE:**

This is a procedure to clean prism surfaces prior to coating.

2.0 REFERENCED DOCUMENTS:

None.

3.0 **Cleaning Equipment:**

Crest Ultrasonic Vapor Degreaser Model # CDU 1410-W
Trichlorethane, Deionized Water, Liquid Detergent (Mr. Clean), Alconox, a pair of plastic covered tweezers, nylon brush, dry Nitrogen gun and holding chamber.

4.0 **Cleaning Set-up:**

4.1 Prepare liquid detergent bath with 50% Mr. Clean and 50% deionized water.
4.2 Prepare Alconox solution from 1/4 teaspoon Alconox in 500 ml deionized water.

5.0 **Cleaning Procedure:**

5.1 Begin "Turn on" procedure for Crest Ultrasonic Degreaser.
   a. Check solvent levels, if low add trichlorethane.
   b. Adjust thermostat settings for 160 deg. F.

c. Open water inlet valves.
d. Turn on "Main Disconnect" switch.
e. Turn on "Main Power" switch.
f. Turn on "Heat" switch.
g. Turn on "Generator" switch
h. Turn on "Pump" switch
i. Check pressure gauge for 20-25 p.s.i.

5.2 Use plastic-covered tweezers to hold a prism by its ground surface.
5.3 Place prisms on degreasing tray.
5.4 Lower degreasing tray into vapors for 10-15 minutes.
5.5 Remove tray from vapors and dip slowly into cleaning tank.
5.6 Place prisms in liquid detergent solution (see step #4.1)

5.7 Continuously rinse prism with deionized water flow.
NOTE: do not allow prism to dry until step #5.9.
5.8 Lightly brush prism with Alconox solution and nylon brush (see step #4.2).
5.9 Repeat step #5.8 until one entire polished surface holds a bead of water when shortly removed from deionized water flow.
5.10 Using Nitrogen gun, lightly blow water off prism face making sure the water moves in one continuous wave.

TITLE: ANTI REFLECTION COATING PROCEDURE FOR PRISMS (SURFACES A & C, LONG LEG, A.R @ NORMAL)

1.0 **SCOPE:**

This is a procedure to coat prism side surfaces with anti-reflection coatings.

2.0 **Reference Documents:**

See attached pages.

3.0 **Coating Equipment**

Coating fixture #1009, 9" Coating Planet, Microscope slides, dry Nitrogen gun, holding chamber, Davis & Wilder Model #400SC3036 Hard Coating Chamber with Panetary Motion, Optical Monitoring system and Inficon Model $IC6000 Physical Monitoring system, SiO_2 and Ta_2O_5 materials, Optical Monitoring chips, Physical Monitoring Quartz Crystals, Vacuum Cleaner lint-free cloth, Acetone and Methanol.

4.0 **Coating Set-Up:**

4.1 Clean prism (see M.P.P. #1).
4.2 Mount prisms and two microscope slides (witness samples).
4.3 Place fixture, with parts, into dry Nitrogen holding chamber.
4.4 Open coating chamber door.
4.5 Empty crucible pot.
4.6 Clean crucible pot with acetone.
4.7 Fill crucible pot with new materials (SiO_2 or Ta_2O_5).
4.8 Check optical monitoring chips
4.9 Change physical monitoring quartz crystals
4.10 Set optical wavelength.

4.11 Adjust optical alignment for maximum signal.
4.12 Check E-Beam filament.
4.13 Wipe down walls of coating chamber with lint-free cloth and methanol or acetone.
4.14 Use vacuum cleaner to remove any dirt or dust accumulated in the chamber.
4.15 Remove fixture with parts from dry nitrogen holding chamber.
4.16 Mount fixture into 9" planet.
4.17 Mount 9" planet, with fixture, into coating chamber.
4.18 Close coating chamber.
4.19 Close vent valve.
4.20 Open roughing valve, evacuate until a pressure of 50 u is attained, then close roughing valve.
4.21 Open High Vacuum valve to 5×10^{6} mm Hg,
4.22 Turn on heat to 220° C.
4.23 Wait for vacuum to reach 5×10^{6} mm Hg (approx. 1 hr.).

5.0 Coating Procedure:

5.1 Follow coating description, file #LLSARO
5.2 Follow coating ticket # 1

5.3 Coating Process

5.3.1

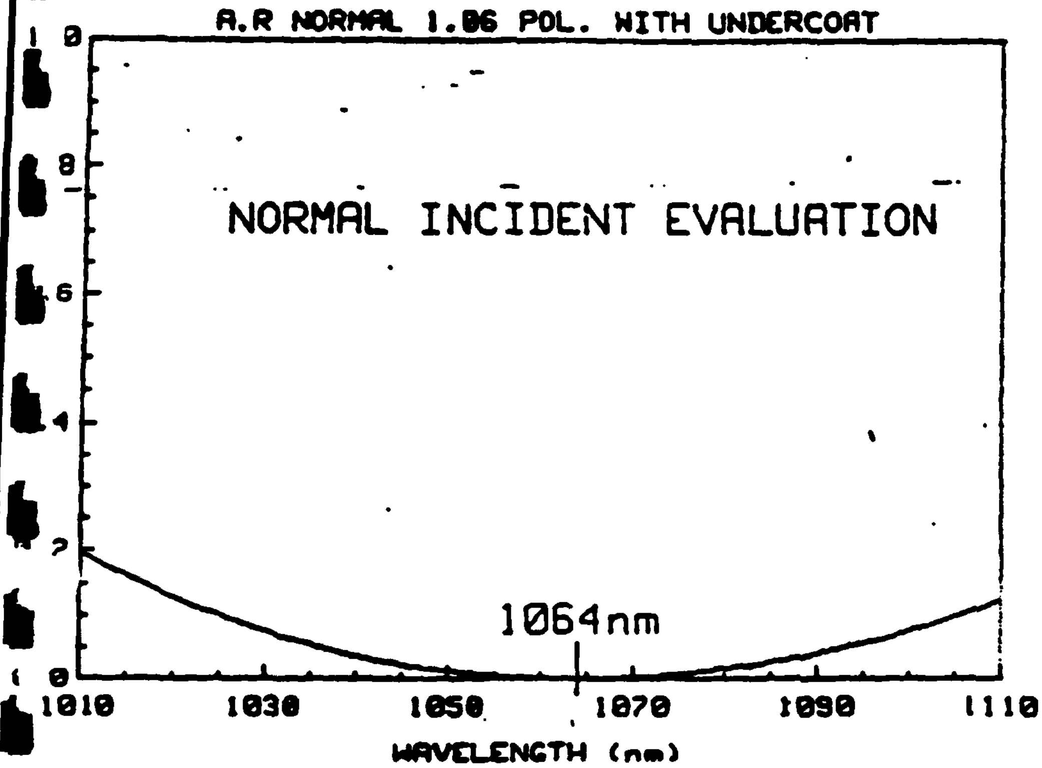
Material:	Ta_2O_5
Supplier:	EM Labs, Type 8172
O_2 Reactive Evaporation Pressure	5.8×10^{-5} torr
Rate:	1.5 angstroms/sec
Substrate Temperature:	220° C
Base Pressure:	$<6 \times 10^{-6}$ torr

5.3.2

Material:	SiO_2
Supplier:	EM Labs, Type 7537
O_2Reactive Evaporation Pressure:	No O_2 bleed
Rate:	4-5 angstroms/sec
Substrate Temperature:	220°C
Base Pressure:	$<6 \times 10^{-6}$ torr

5.4 Turn off heat. Let chamber cool to 80°C.
5.5 Close High Vacuum Valve.
5.6 Open Vent valve
5.7 Remove 9" planet.
5.8 Remove fixture from 9" planet.
5.9 Remove prisms from fixture.

LLSARO



n Division Litton Industries - program GTFE 11 Jul 1986 4:08 PM

: LLSARO NORMAL AR ON LLS POLARIZER CUBE WITH 1/2 WAVE UNDERCOAT, DISK #9

(from SUBSTRATE) - file LLSARO + ABS MATERIAL * PHYS THICKNESS

.5S 2 .10046M 3 .31757S

0 design WAVE 1064 nm FORWARD CALC

SYMBOL	n	k	INDEX FILE
AIR	1	0	
SUB			BK7
H			TIO2
S	1.46	0	
M			TA2O5
L	1.38	0	
A			AL2O3

COATING RICK #1

CHANGE CHIP 1✓. CHIPS REMAINING 15. CHECK WAVELENGTH ✓.

Monitor Chip # 1
ROD HEIGHT=8.538 MONITOR/WORK (H)=1.218 MONITOR/WORK (L)=1.246
****

Film layr #	Chip layr #	D$	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO	kANG	TIME
1	1	.55	475	4.26	2.81	4.26	3.75	1.000d	4.651			

CHANGE CHIP ✓. CHIPS REMAINING 14. CHECK WAVELENGTH ✓.

Monitor Chip # 2
ROD HEIGHT=8.538 MONITOR/WORK (H)=1.218 MONITOR/WORK (L)=1.246
****

Film layr #	Chip layr #	D$	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO	kANG	TIME
2	1	.10046M	465	4.26	4.26	24.37	22.45	-0.000	1.096			
3	2	.31757S	465	22.45	1.99	22.84	19.94	0.981d	2.861			

NO MORE LAYERS. DESIGN COMPLETE!

TITLE: ANTI REFLECTION COATING PROCEDURE FOR PRISMS
(Surfaces B & E, Short Leg, A.r. @ 13^{o})

1.0 SCOPE

This is a procedure to coat prism side surfaces with anti-reflection coatings.

2.0 Reference Documents:

AIRTON M.P.P. #1

3.0 Coating Equipment:

Coating fixture 1007, 9" Coating Planet, Microscope slides, dry Nitrogen gun, holding chamber, Davis & Wilder Model #400SC3035 Hard Coating Chamber with Planetary Motion, Optical Monitoring system and Inficon Model # IC6000 Physical Monitoring system, SiO_2 and Ta_2O_5 materials, Optical Monitoring chips, Physical Monitoring Quartz Crystals, Vacuum Cleaner, lint-free Cloth, Acetone, and Methanol.

4.0 Coating Set-Up:

4.1 Clean prism (see M.P.P. #1) Steps 5.2 thru 5.10 only.
4.2 Mount prisms and two microscope slides (witness samples) in coating fixture #1007.
4.3 Place fixture, with parts, into dry Nitrogen holding chamber.
4.4 Open coating chamber door.
4.5 Empty crucible pot.
4.6 Clean crucible pot with acetone.
4.7 Fill crucible pot with new materials (SiO_2 or Ta_2O_5)
4.8 Check optical monitoring chips.
4.9 Change physical monitoring quartz crystals.
4.10 Set optical wavelength.
4.11 Adjust optical alignment for maximum signal.

4.12 Check E-Beam filament.
4.13 Wipe down walls of coating chamber with lint-free cloth and methanol or acetone.
4.14 Use vacuum cleaner to remove any dirt or dust accumulated in the chamber.
4.15 Remove fixture with parts from dry Nitrogen holding chamber.
4.16 Mount fixture into 9" planet.
4.17 Mount 9" planet, with fixture, into coating chamber.
4.18 Close coating chamber.
4.19 Close vent valve.
4.20 Open roughing valve evacuate until a pressure of 50 u is obtained, then close roughing valve.
4.21 Open High Vacuum valve tro 5×10^{6} mm Hg.
4.22 Turn on heat to 220°C.
4.23 Wait for vacuum to reach 5×10^{6} mm Hg. (approx. 1 hr.).

5.0 Coating Procedure:

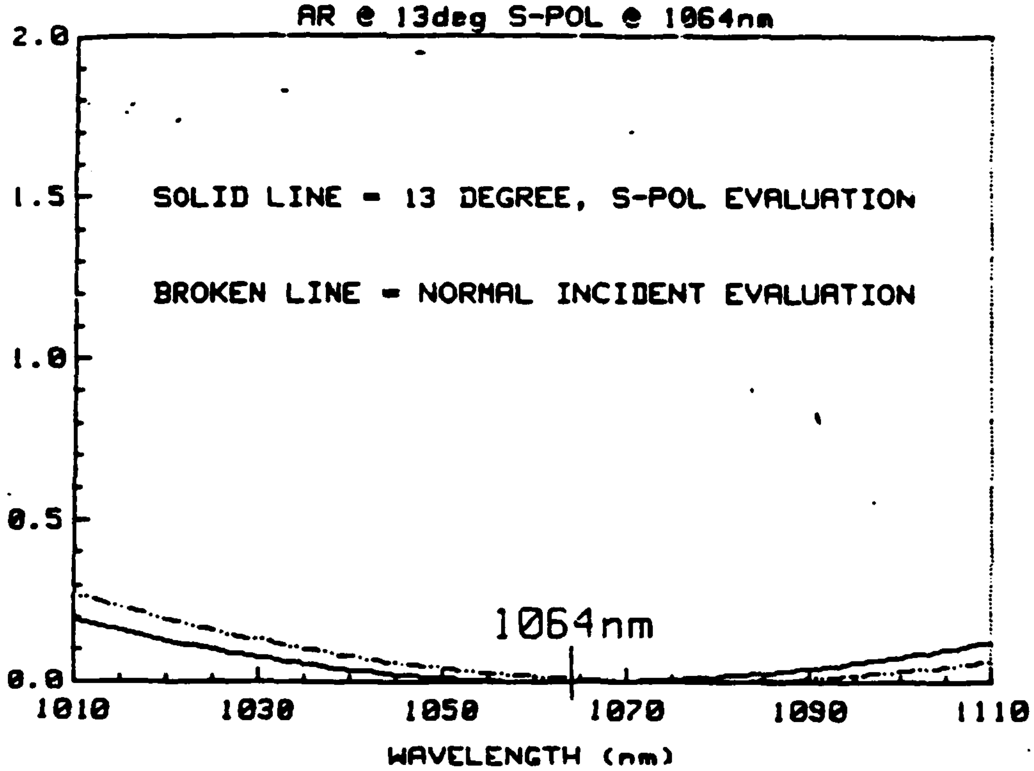
5.1 Follow coating description, file #LLSAR13
5.2 Follow coating ticket #2.

5.3 Coating Process:

5.3.1	Material:	Ta_2O_5
	Supplier	EM Labs, Type 8172
	O_2 Reactive Evaporation Pressure:	5.8×10^{-5} torr
	Rate:	1.5 angstroms/sec
	Substrate Temperature:	220°C
	Base Pressure:	$<6 \times 10^{-6}$ torr
5.3.2	Material:	SiO_2
	Supplier:	EM Labs, Type 7537
	O_2 Reactive Evaporation Pressure:	No 0 bleed
	Rate:	4-5 angstroms/sec
	Substrate Temperature:	220°C
	Base Pressure:	$<6 \times 10^{-6}$ torr

5.4 Turn off heat. Let chamber cool to 80°C
5.5 Close High Vacuum valve.
5.6 Open vent valve.
5.7 Remove 9" planet.
5.8 Remove fixture from 9" planet
5.9 Remove prisms from fixture.

LLSAR13



tron Division Litton Industries - program GTFE 2 Oct 1986 3:28 AM

S 1064nm CUBE POLARIZER: 13 DEGREE S-POL EXIT FACE AR, FILE LLSAR13, DISK #9

STGN (from SUBSTRATE) - file LLSAR13 + ABS MATERIAL * PHYS THICKNESS

1 .50613S 2 .099829M 3 .32076S

E 13 s POL design WAVE 1064 nm FORWARD CALC

SYMBOL	n	k	INDEX FILE
AIR	1	0	
SUB			BK7
H			TIO2
S	1.45	0	
M			TA2O5
L	1.38	0	
A			AL2O3

COATING TICKET #2.

iter Chip # 1
D HEIGHT=8.538 MONITOR/WORK (H)=1.218 MONITOR/
##
Chip
r layer

#	OS	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO
1	.5L	475	4.26	2.81	4.26	3.75	1.000d	4.651	

ANGE CHIP_1_. CHIPS REMAINING_10_. CHECK WAVELE

nitor Chip # 2
HEIGHT=8.538 MONITOR/WORK (H)=1.218 MONITOR/
##
m Chip
layer

#	OS	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO
1	.10318M	475	4.26	4.26	24.22	22.24	0.000	1.099	
2	.32079L	475	22.24	1.91	22.65	18.91	0.980d	2.820	

TITLE: POLARIZATION COATING PROCEDURE FOR PRISMS (HYPOTENUSE FACE)

1.0 **SCOPE:**

This is a procedure to coat prism hypotenuse surfaces with a polarization coating.

2.0 **Reference Documents:**

See AIRTON M.P.P. #1

3.0 **Coating Equipment:**

Coating fixture #1158, 9" Coating Planet, Microscope slides, dry Nitrogen holding chamber, Davis & Wilder Model #400SC3036 Hard Coating Chamber with Planetary Motion, Optical Monitoring System and Inficon Model #1C6000 Physical Monitoring System, SiO_2 and Ta_2O_5 materials, Optical Monitoring chips, Physical Monitoring Quartz crystals, vacuum cleaner, lint-free cloth, Acetone, Methanol and a Bake Oven.

4.0 **Coating Set-Up:**

4.1 Clean Prisms (see M.P.P. #1) Steps 5.2 thru 5.10 only.

4.2 Mount prisms and two microscope slides (witness samples) in coating fixture # 1158.

4.3 Place fixture, with parts mounted, into dry Nitrogen holding chamber.

4.4 Open coating chamber door.

4.5 Empty crucible.

4.6 Clean crucible pot.

4.7 Fill crucible pot with new material (SiO_2 or Ta_2O_5).

4.8 Check optical monitoring chips.

4.9 Change physical monitoring quartz crystals.

4.10 Set optical wavelength.

4.11 Adjust optical alignment for maximum signal.

4.12 Check E-Beam

4.13 Wipe down walls of coating chamber with lintfree cloth and methanol or acetone.

4.14 Use vacuum cleaner to remove any dirt or dust accumbulated in the chamber.

4.15 Remove fixture, with parts mounted, from dry nitrogen holding chamber.

4.16 Mount fixture into 9" planet.

4.17 Mount 9" planet, with fixture, into coating chamber.

4.18 Close coating chamber.

4.19 Close vent valve.

4.20 Open roughing valve evacuate until a pressure of 50 u is attained, then close roughing valve.

4.21 Open High Vacuum valve to 5×10^6 mm Hg.

4.22 Turn on heat to 220°C.

4.23 Wait for vacuum to reach 5×10^6 mm Hg (approx. 1 hr.).

5.0 Coating Procedure:

5.1 Follow coating description, file # FML Jones 6.

5.2 Follow coating ticket #3.

5.3 Coating Process

5.3.1. Material: Ta_2O_5
Supplier: EM Labs, Type 8172
O_2Reactive Evaporation Pressure: 5.8×10^{-5} torr
Substrate Temperature: 220°C
Base Pressure: $\angle 6 \times 10^{-6}$ torr

5.3.2	Material:	SiO_2
	Supplier:	EM Labs, Type 7537
	O_2 Reactive Evaporation Pressure:	No. O_2 bleed
	Rate:	4-5 angstroms/sec
	Substrate Temperature:	220°C
	Base Pressure:	$< 6 \times 10^{-6}$ torr

5.4 Turn off heat. Let chamber cool to 80° C.

5.5 Close High Vacuum valve.

5.6 Open vent valve.

5.7 Remove 9" planet

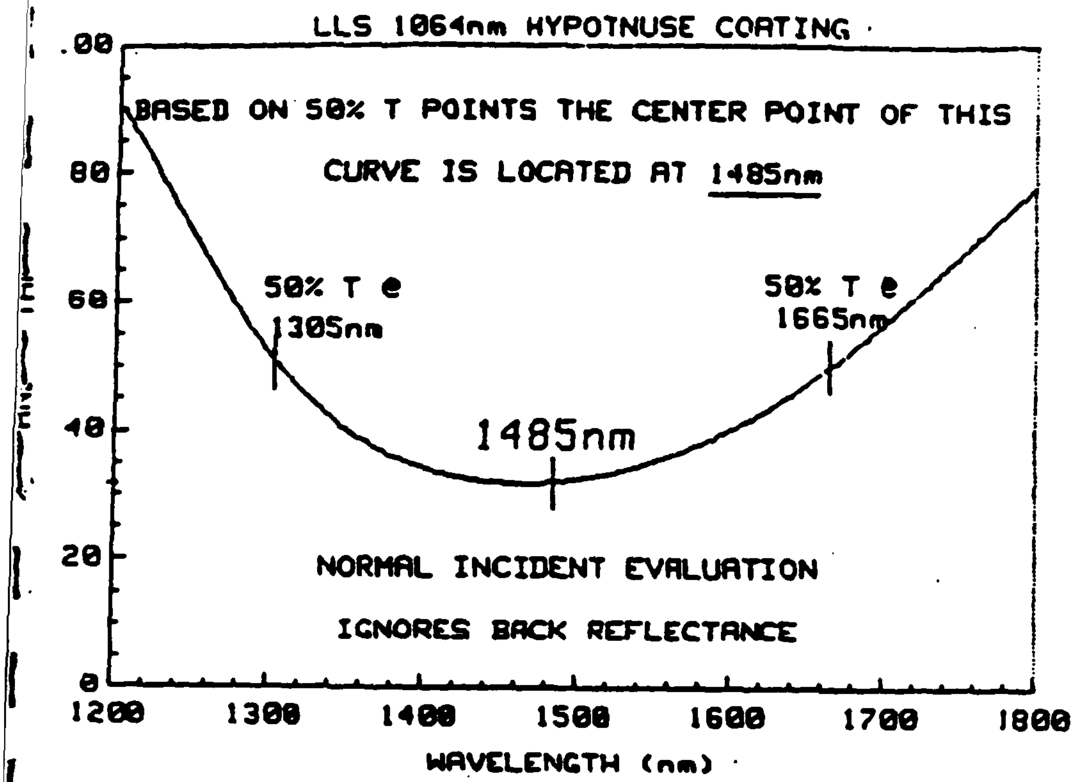
5.8 Place 9" planet in bake oven (325°) for 10 hours. Refer to S.P.P. 1004.

5.9 Remove 9" planet from oven.

5.10 Remove fixture from planet.

5.11 Remove prisms from fixture.

LLS-6



tron Division Litton Industries - program GTFE 8 Sep 1986 1:34 AM

LITTON LASER 1064nm POLARIZER HYPOTNUSE COATING

T^N (from SUBSTRATE) + ABS MATERIAL * PHYS THICKNESS

1	.5S	2	.25M	3	.25S	4	.25M	5	.25S
6	.25M	7	.5S						

0 design WAVE 1465 nm FORWARD CALC

SYMBOL	n	k	INDEX FILE
AIR	1	0	
SUB			BK7
H			TIO2
S	1.46	0	
M			TA2O5
L	1.38	0	
A			AL2O3

COATING TICKET #3

.GE CHIP____. CHIPS REMAINING 17_. CHECK WAVELENGTH 650_.

Monitor Chip # 1
HEIGHT=0.538/ MONITOR/WORK (H)=1.218 MONITOR/WORK (L)=1.246

n Chip
r layr

#	#	QS	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO	LANG	TIME
	1	.55	650	4.26	.2.01	4.26	3.63	1.000d	4.565		5.371	20:45

ANGE CHIP_✓_. CHIPS REMAINING_16_. CHECK WAVELENGTH_576_.

Monitor Chip # 2
OD HEIGHT=0.538 MONITOR/WORK (H)=1.218 MONITOR/WORK (L)=1.246

Chip
layr

#	#	QS	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO	LANG	TIME
	1	.25M	575	4.26	4.26	23.11	20.29	-0.000	3.150	[illegible]	[illegible]	[illegible]
	2	.255	575	20.29	1.31	20.88	4.89	0.970d	2.183		[illegible]	[illegible]
	3	.25M	575	4.89	0.67	45.21	33.61	0.905i	2.260	[illegible]	[illegible]	[illegible]
	4	.255	575	33.61	10.45	37.58	23.18	0.854d	2.469		[illegible]	[illegible]

HANGE CHIP__2_. CHIPS REMAINING_15_. CHECK WAVELENGTH 522.

Monitor Chip # 3
HEIGHT=0.538 MONITOR/WORK (H)=1.218 MONITOR/WORK (L)=1.246

in Chip
r layr

#	#	QS	Mono	Rinit	Rmin	Rmax	REFL	PARTIAL	FULL	RATIO	LANG	TIME
	1	.25M	575	4.26	4.26	23.11	20.29	-0.000	3.150		1.825	[illegible]
7	2	.55	575	20.29	1.31	20.88	15.44	0.970d	3.278		5.235	[illegible]

NO MORE LAYERS. DESIGN COMPLETE!

M.P.P. NO: 5

Page: 1 of 1

Date: December 17, 1987

TITLE: METHOD FOR ANNEALING OPTICAL COATINGS

1.0 Scope:

This is a procedure to anneal optical coatings to reduce absorbtion and densify the coating.

2.0 Reference Documents:

Blue M Model # POM-70 Operating Manual P.

3.0 Production Equipment:

Blue M Model # POM-70 Convection Oven and prism coating fixture

4.0 Production Procedure:

4.1 Place fixture with prisms in oven
4.2 Set Timer to 12 hours
4.3 Set Temperature Control to 325°c
4.4 Set OTP Control to 335°c
4.5 Turn on Main Power Switch. If Control Failure Pilot light is on. press OTP Reset Device
4.6 Wait one hour after timer turns off the oven
4.7 Open exhaust vents
4.8 Wait one hour then remove fixture and place it in a warming oven at 80°C.

Date: December 17, 1987

TITLE: AIR GAP PRISM PAD THICKNESS CALCULATION PROCEDURE

1.0 SCOPE:

This procedure will detail the method used to calculate optional pad thickness for an air gap prism based on an actual prism coating run.

2.0 Reference Documents

S.I.P. NO. 9 and M.P.P. #4

3.0 Design Equipment

Hewlett Packard 9836 Computer
Hewlett Packard 2671G Graphics Printer
FTG Software's Film*Star Thin Film Evaluation Program
Basic 4.0 System Disc
Basic 4.0 Drivers/Language Extensions Disc

4.0 Computer Set-Up

4.1 Insert the current Film*Star data disc into disc drive #1 of the HP 9836 computer.

4.2 Insert the Basic 4.0 system disc into drive #0 of the computer and turn the power on.

4.3 When the screen reads "remove BASIC 4.0 SYSTEM, insert DRIVERS/EXTENSIONS [cont]" remove the Basic System disc and insert the Basic 4.0 Drivers/Language Extensions disc into drive #0 and press the continue switch.

4.4. When the screen reads "remove 4.0 DRIVERS + EXTENSIONS, insert Film*Star disc [cont]" remove the Drivers/Extensions disc and insert Film*Star Program disc #1. General Thin Film Evaluation (GTFE) # 1 Start. Press Continue.

4.5 Modify the Film*Star system configuration as needed or if no changes are required press Continue.

4.6 The screen will display the Film*Star licensing rights and requirements. Read, then press Continue.

4.7 Program choices are offered. Use softkey K5 to select GTFE. When the first part of GTFE is loaded, the screen will read "File GTFE - IEM4 NOT ON LINE. Insert GTFE #2. [enter] when ready". Remove GTFE #1 and insert Film*Star program disc #2 GTFE #2 into drive #0. Press Enter.

4.8 The screen will now read "load FILM from DISC - file name?". Press Enter.

4.9 Press the letter I on the keyboard. The screen will read "load INDEX MENU from DISC - file name?". Type in the word "HARD" and press Enter.

4.10 Move the curser wheel until it overlaps FUS - SIL. Press the CLR LN (clear line) softkey and type in BK7. When the computer asks to store HARD on disc, press CLR LN, then Enter.

4.11 Press the softkey that now states "/FWD IGN Sd2/" once so that it reads "/FWD INC Sd2/". This step will include back surface reflection in a calculation consistent with a transmission curve.

4.12 Press the "PROGRAM MODE" softkey (ko). Type in "T" for plot type (transmission) press Enter. The screen will now ask "VS..........." The default valve is "W" (wavelength), press Enter. The screen now asks "load GRAPH AXES from DISC-file name?" Leave blank and press Enter.

4.13 Using the curser wheel for movement, the following values are typed in; WAVE min: 1200. WAVE max: 1800. WAVE delta: 2, TIC intvl: 20, LBL intvl; 100, FIX:0, T min:0, T max=100. TIC intvl: 5, LBL intvl:20, FIX:0. GRAPH TITLE: Type in coating run number, then ":Prism Coating Evaluation". Press Enter twice.

4.14 Press the letter "D" on the keyboard. This is the design menu. Press the "Enter from KBD" softkey (K5). For design DESCRIPTION type in "Run (coating run #); Evaluation of coating to determine optimal pad thickness". Press Enter. The screen will now read "ENTER FILM DESIGN STARTING at SUBSTRATE:" The theoretical coating design for one prism half is entered as follows: Type in .5S, press Enter, press the proceed softkey (K5). For the "ENTER NEXT LAYER: ($ ENDS CONSTRUCTION)" prompt, type in .25M, press Enter, press the proceed softkey & use the same process to input the following layers: .25S, .25M, 25S, 25M, and 5S. After pressing the proceed softkey for the last (.5S) layer, enter the $ symbol. Press Enter to end design construction. Input 1465 as the DESIGN WAVELENGTH. Press Enter. No hard copy is required, so press Enter.

4.15 Press the letter "O" on the keyboard. Press the "opti VARIABLES" softkey (K2).then press Enter. The grid represents layer number to be varied, so type in 1 through 7, each number in a separate box. Press Enter twice to get to softkeys.

4.16 Press the "opti TARGETS" softkey (K1), then Enter. The grid that appears has, in succession, spots for T: transmission or reflection. WAVE: wavelength. TARG: percent T or R required. TOL: plus/minus tolerance allowed from target. ANG: angle and P: polarization. In this step T is always 2 (transmission). TOL is 1. ANG is 0. and POL is 3 (random). It is now necessary to obtain an after bake transmission curve of the coating run to be optimized. From this curve. at 40 nm intervals from 1200 nm. the valves of wavelength vs. transmission are first recorded then entered in the appropriate headings of the optimization variables grid. There will be 16 targets. all in the same format. For example, if at 1200 nm the transmission on the curve was 90%. the target for that point would be set up as follows: T=2. WAVE= 1200. TARG= 90, TOL= 1, ANg= 0. and P= 3. When the grid has been completed. press Enter. If the targets are to be stored. type in an 8 character or less file name which can be re-entered after pressing the "opti TARGETS" softkey. If no file is required. press Enter to return to the softkeys.

5.0 PAD THICKNESS CALCULATION

5.1 Press the opti BEGIN softkey (K5). 14 vertical lines first appear corresponding to each point input as an optimization target. These lines, if input properly, will take the same shape as the transmission curve. Next an "X" will appear near each line, close but not exactly on the line it relates to. The X's represent the theoretical performance of the design entered in step 4.14, while the lines represent how close the actual coating run was to the design. In the lower left of the screen "ITER?" will show with a zero below it. Punch in the number of optimization cycles required (usually about 10). Press Enter. "MIN Q" , appearing in the lower left of the screen. designates the smallest layer thickness allowed. Press Enter as this parameter is not critical to this calculation. The display will now read "DAMP?". which is an arbitrary variable that controls the amount each layer is allowed to change in each calculation. Press the CLR LN softkey and enter 1000 as the damping function. Press Enter. As the optimization progresses. the X's will approach the shape of the coating run optimization targets. In effect. the theoretical design is being modified to the performance of the actual coating run. The resulting layer thicknesses are representative of the errors that occurred during the coating run. As the optimization progresses. the merit function at the top of the screen will get smaller as the design approaches its optimization targets. The merit function represents the difference between the design being evaluated and the optimization targets. At the same time the damping function will decrease. as long as the design is being improved. If an iteration results in a worsening of the design the damping function will increase. and the best design will be kept in memory. The normal optimization cycle will produce a series of improvements followed by a series of failures. If 10 iterations do not provide a satisfactory result. optimization may be continued by pressing the "opti CONTINUE' softkey (K6) and pressing Enter. Optimization may be stopped in progress by pressing Q waiting for a quit calculation statement and pressing Enter.

5.2 Press the number "1" on the keyboard. Turn on the HP2671G graphics printer. Press softkey K0; "draw NEW AXES". then "EVAL % T" (K5). make sure the design wavelength is 1465. press Enter. run line type 1. press Enter. When the curve is finished. press the "DUMP GRAPHICS" softkey (K3). When the printing is finished and the softkeys return. press D for design menu. "review DESIGN" softkey

(K3), a "Y" for hard copy and Enter. Advance the paper to the next sheet by pressing the form feed key on the printer.

5.3 Press the letter "I" to get the index table. Do not load a table, press Enter. The curser will be at AIR, n=1. Press the CLR LN softkey and move to the file section of AIR. Type in a "BK7". Scroll through to the blank line after "A". Type in a "G" as a symbol under the "A", move one spot under the heading "t" and type in a "*" to allow the air gap to be entered as a physical thickness. Move one more spot to the section for "n", and type in a "1". These steps allow G to be the index of refraction of the air gap (n=1) and, because light is coming to the coating through the prism and exiting through the prism, lets the substrate and the incident medium (AIR) be BK7. Press Enter twice to return to the softkeys.

5.4 Press "D" to get the design menu. Press the "change DESIGN" softkey (K7). Do not change the description, press Enter. For layer number, press 8 then Enter. Layer 8 will represent the air gap of an assembled prism. Input the theoretical design valve of 650G. which is a physical thickness of 650 nm. Press Enter, press 9, then enter to input layer 9. Both sides of an assembled prism are from the same coating run, so it can be assumed that the design just optimized is the same for both sides of the prism. Applying this symmetry, layer 1=layer 9, layer 2=10....layer 7=15. The valve shown for layer 1 is now entered for layer 9, and so on to layer 15 being the same as layer 7. After entering layer 15, leave the layer # request blank and press Enter to exit. Design wavelength is unchanged, so press Enter twice to return to softkeys.

5.5 Press the letter "S" to get to the set-up menu. Press softkey K3 "/FWD inc sd2/" four times until it reads "/FWD ign sd 2/".

5.6 Press the letter "O" to get to the optimization menu. Press the "opti VARIABLES" SOFTKEY (K2). Input a "*" and press Enter to clear existing optimization variables.. As the design is fixed the only variable will be the air gap, so press 8 for layer 8, and press Enter twice.

5.7 Press the "opti TARGETS" softkey (K2), press "*" and Enter to clear current targets, answer "N" to auto generate. Load the following sets of optimization targets: #1) T=2, WAVE=1064, TARG=100, TOL=0.5, ANG=41, POL=1, which creates a target for polarization to be 100% transmitted at 1064 nm at 41 degrees. #2), WAVE=1064, TARG=0, TOL=0.5, ANG-41, POL=2, which creates a target for S-polarization to % transmitted (100% reflected) at 1064 nm at 41 degrees. Press Enter twice to return to softkeys.

5.8 Press "G" to get graph axes, press Enter. Enter the graph variables to read: WAVE min = 1010, WAVE max = 1110, WAVE delta = 2. TIC intvl = 5. LBL intvl=20, FIX = 0, T min = 0, T max = 100, TIC intvl - 5, LBL intvl = 20, FIX = 0, and GRAPH TITLE = "(run number) with optimized pad thickness" Press Enter twice to return to softkeys.

5.9 Press the letter "O" to return to the optimization menu. Press opti BEGIN, softkey (K5). Set iterations to 10, press Enter, min Q to 0, press Enter and damping to 50, press Enter. Run through approximately 30 iteration using the opti CONTINUE softkey, or until the design stops showing improvement.

5.10 Press the letter "A". For angle of incidence, input 41 and press Enter. For polarization. input P then press Enter.

5.11 Press the number "1" to get to the evaluation menu. Press softkey (K0) to draw new axes. then (K5) to evaluate % T. using the design wavelength of 1465 and line type 1.

5.12 Press the letter "A". leave the angle at 41. press Enter. Change the polarization to S. press Enter.

5.13 Press number "1". Do not draw new axes, but press softkey (K5) EVAL % T. Use line type 8.

5.14 After plot to complete. press "DUMP GRAPHICS" softkey (K2).

5.15 Press "D" for design menu. "review DESIGN" softkey (K2) and respond "Y" for a hard copy.

5.16 Press form feed on the printer and remove graphs for records of optimization of pad thickness. The physical thickness value for layer 8 represents the optimal pad thickness for the coating run evaluated. This value is reduced by 4% and pads of the resulting physical thickness are deposited on the coated prism halves.

M.P.P. NO: 7

Date: December 17, 1987

TITLE: **PAD DEPOSITION PROCEDURE FOR PRISMS**

1.0 **SCOPE:**

This is a procedure to deposit pads on prism hypotenuse surfaces.

2.0 **Reference Documents:**

See M.P.P. #1

3.0 **Coating Equipment:**

Coating fixtures #1010, and # 090, 9" coating planet, microscope slides, dry Nitrogen holding chamber, Davis & Wilder Model #400SC3036 hard coating chamber with planetary motion, Inficon Model #IC6000 physical monitoring system, Ta_2O_5 materials, physical monitoring quartz crystals, vacuum cleaner, lint-free cloth, acetone, methanol and bake oven.

4.0 **Coating Set-Up:**

4.1 Clean prisms (See M.P.P. #1) Steps 5.2 thru 5.10 only.
4.2 Mount prisms in coating fixture #090.
4.3 Mount fixture #090 and two microscope slides (witness samples) in coating fixture #1010.
4.4 Place fixture into dry Nitrogen holding chamber.
4.5 Open coating chamber door.
4.6 Empty crucible pot
4.7 Clean crucible pot with acetone.
4.8 Fill crucible pot with new material (Ta_2O_5)
4.9 Change physical monitoring quartz crystals.
4.10 Set optical wavelength.
4.11 Adjust optical alignment for maximum signal.
4.12 Check E-beam filament.

4.13 Wipe down walls of coating chamber with lint-free cloth and methanol or acetone.

4.14 Use vacuum cleaner to remove any dirt or dust accumulated in the chamber.

4.15 Remove fixtures from dry Nitrogen holding chamber.

4.16 Mount fixtures into 9" planet.

4.17 Mount 9" planet, with fixtures, into coating chamber.

4.18 Close coating chamber.

4.19 Close vent valve.

4.20 Open roughing valve evacuate until a pressure of 50 u is attained, then close roughing valve.

4.21 Open High Vacuum valve to 5×10^{6} mm hg.

4.22 Wait for vacuum to reach 5×10^{6} mm hg. (approx. 1 hr.)

4.23 Do not heat substrate.

5.0 Coating Procedure:

5.1 After determination of Pad Thickness (refer to S.P.P. 1005.) The I C 6000 is used to control the Ta_2O_5 thickness, a density of 8.2 and a tooling factor of 100% is entered. No heat or O_2 bleed is used. Deposition rate is 1.5 A/Sec.

M.P.P. NO: 8

Date: December 17, 1987

TITLE ASSEMBLY PROCEDURE FOR POLARIZING PRISMS

1.0. **SCOPE:**

This is a procedure to assemble polarizing prisms.

2.0 **Reference Documents:**

Standard Inspection Procedure #7

3.0 **Assembly Equipment:**

Neslab Model #HX-50 Refrigerating Recirculator, Spectra-Physics Model #102-4 HeNe Laser, C.V.I. Model #C-90 Nd:YAG Laser, Proteus Industries Model #100C Fluid Flow Switch, Laser Precision Model # CTX-532 Chopper, Newport Model #900 Collimator, Karl Lambrecht Model #MGLA-15-VI064 Glan Laser Prism Polarizer, 2 Karl Lambrecht Model #MW2A-15-V1064 Wollaston Prism Polarizers, Tektronix Model # 2445 Oscilloscope, Laser Precision Model #RK 5200 Power Ratiometer, 3 Laser Precision Model # RKP-545 RX detector probes, Airtron Dichroic Mirror (HR@1.06 um @ 45°/BBAR VIS), 1/16" Aperture, Airtron Part #A12-12 Half Wave Plate @ 1.06 um, a microscope slide, 2 1st Surface Metal Mirrors. Airtron Prism Assembly/Test Fixture, Coherent Model #201 Power Meter and Pyroelectric Detector, Hamamatsu Quadrant Detector with Simpson Digital Readout Display, United Detector Technology Model #61 Optometer with Silicon Detector, Standard Polarizer, F.J.W.I.R. Finder Viewer, Summers Laboratories Model #UV-71 Cement, nylon-tipped tweezers, stainless-steel probe.

Nikon AFX - 11T Microscope
Bausch & Lomb Microscope
Fisher Scientific Microscope Slides
Texlite U.V. Curing Lamp
Vacuum Tweezers

4.0 Cementing of Prisms

4.1 Clean prisms per M.P.P. #1. Steps 5.2 thru 5.10 only.
4.2 Place prism in fixture #601001.
4.3 Inspect prisms for cleanliness using Bausch & Lomb microscope. at 20X. If necessary spot clean using acetone and a Q-tip.
4.4 Place prism without pads into cementing fixture using stainless steel probe. Place one large drop of OU-71 cement on a microscope slide.
4.5 Place prism with pads into fixture #601001 and place under microscope (10X).
4.6 Deposit 3 small drops of cement behind the deposited pads (two corners and the center).
4.7 Pick up prism with nylon tipped tweezers and place on a piece of lens tissue (AR face).
4.8 Using vacuum tweezers pick up prism from ground edge and place it in cementing fixture close to but not touching the prism without pads.
4.9 Insert prism clamping chuck between prism corner and fixture micrometer. Before joining prisms together, blow off both prism hypotenuse with nitrogen gas. This is important! If dust is between prisms, problems witll be encountered.

5.0 Contact prisms by tightening micrometer. A minimum amount of force should be used.

6.0 Optimization and Final Assembly of Prisms:

6.1 Refer to SIP for procedure to test polarizing prisms.
6.2 After SIP setup procedure has been satisfied, record A + B value from ratiometer. This is the reference ratio and implies 100% transmission of the "P" component.
6.3 Insert cementing fixture with prism into test chamber. Tighten set screw to lock fixture into place.
6.4 To adjust for roll and tilt of prism, refer to SIP step #4.37.
6.5 While watching ratiometer, tighten micrometer until a minimum value is obtained. the optimum value would be the same as that recorded in step 6.2. At this point you can calculate Tp.

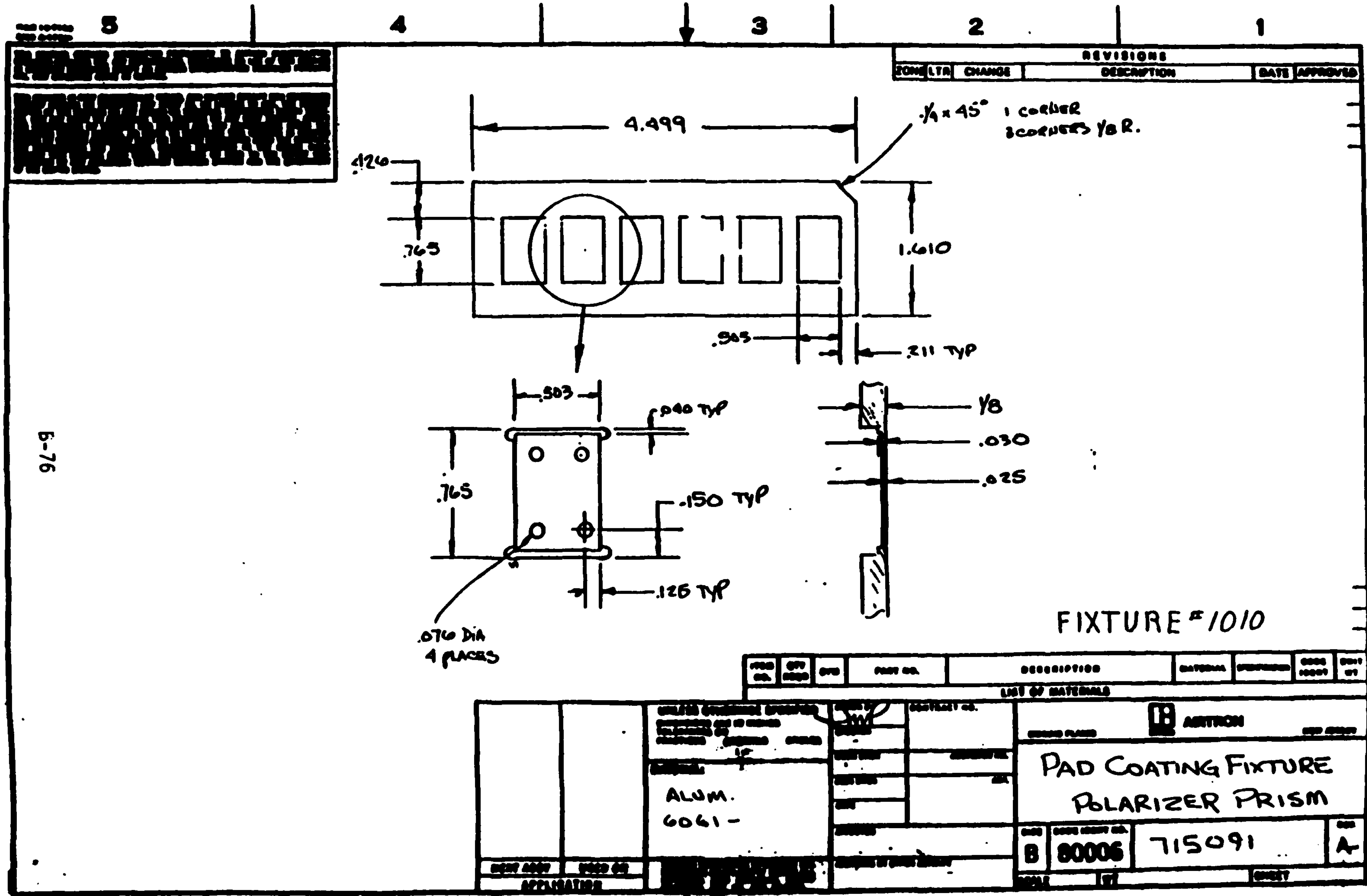
$$Tp = 100 \times \frac{\text{Reading without Polarizer}}{\text{Reading with Polarizer}}$$

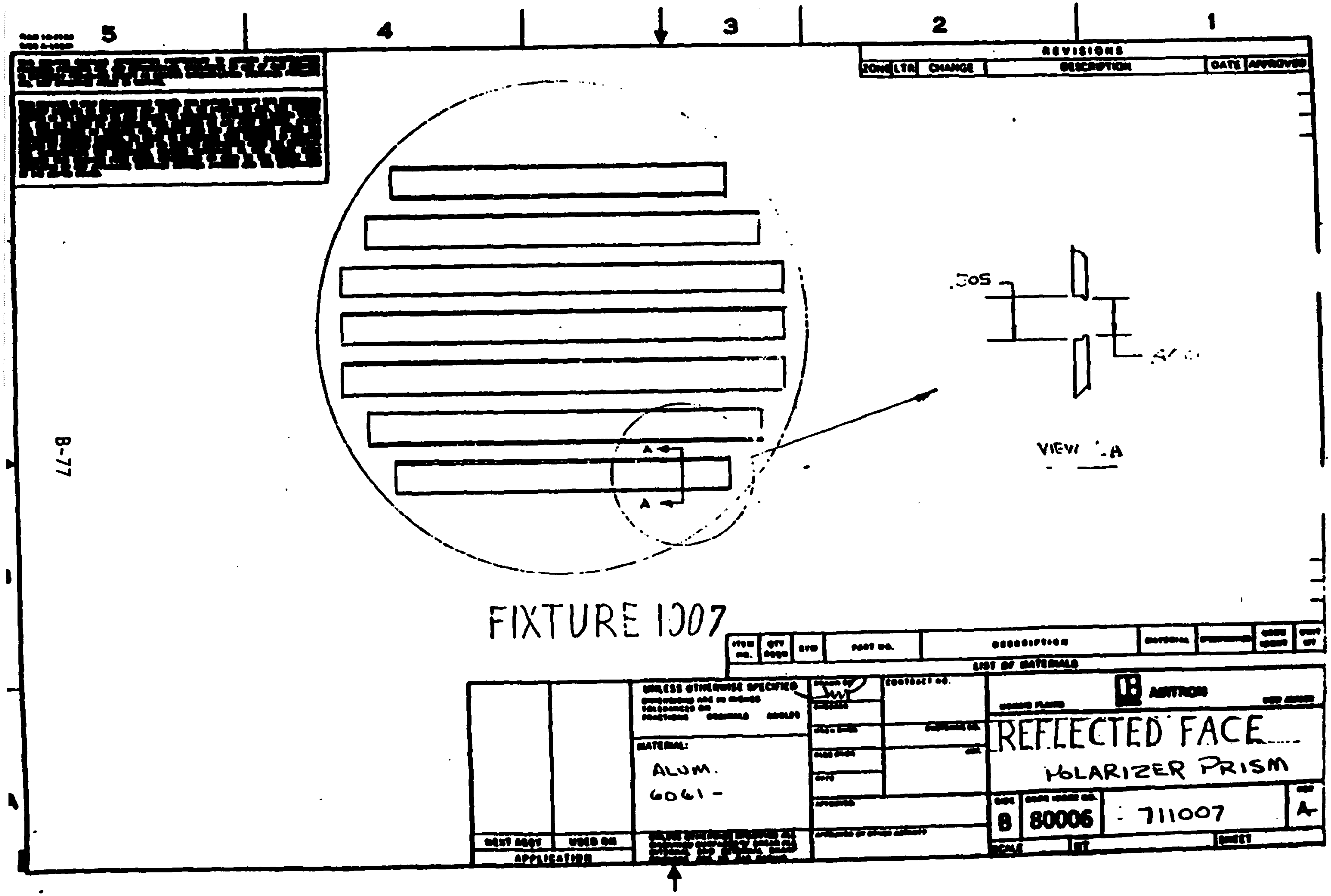
6.6 To "lock" prism into place, it is necessary to cure the UV-71 cement. This is accomplished by a four minute exposure time using the Texlite UV lamp. An iterative 30 second cure per side is used.
6.7 Loosen micrometer. If cube has been cured properly, no change on the ratiometer will occur.
6.8 Remove cube from cementing fixture and edge seal. This is accomplished by viewing the cube under 5X magnification with the Nikon microscope.

6.9 Using the stainless steel probe, run a bead of UV-71 cement along the diagonal of the cube (both sides) and curvé for 4 minutes. An iterative 30 second cure per side is used.

6.10 Repeat 6.9 on both short sides of the cube.

6.11 Assembly is now complete.


REVISIONS
ZONE LTR CHANGE DESCRIPTION DATE APPROVED
4.499
.1/4 x 45° 1 CORNER
3 CORNERS 1/8 R.
.126
.765
1.610
.505
.211 TYP
.503
.040 TYP
.765
.150 TYP
.125 TYP
.076 DIA
4 PLACES
1/8
.030
.025
FIXTURE #1010
LIST OF MATERIALS
ALUM.
6061 -
PAD COATING FIXTURE
POLARIZER PRISM
B 80006 715091 A



5
4
3
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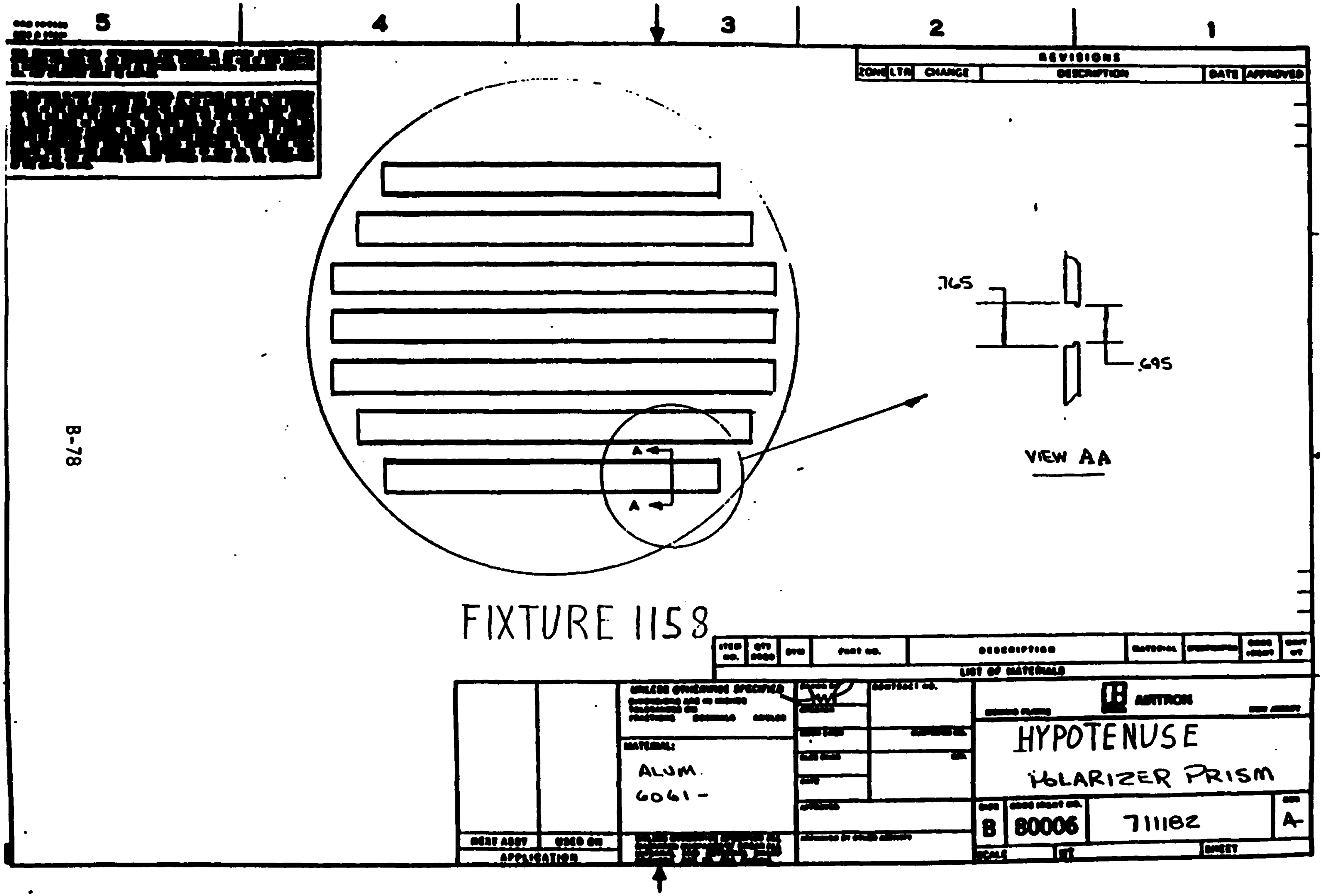
1
REVISIONS
ZONE
LTR
CHANGE
DESCRIPTION
DATE
APPROVED
.305
VIEW A
A
A
FIXTURE 1007
ITEM NO.
QTY REQD
PART NO.
DESCRIPTION
MATERIAL
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED
CONTRACT NO.
MATERIAL:
ALUM.
6061-
REFLECTED FACE
POLARIZER PRISM
B
80006
711007
A
NEXT ASSY
USED ON
APPLICATION
SCALE
SHEET


5
4
3
2
1
REVISIONS
ZONE
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CHANGE
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DATE
APPROVED
.765
.695
VIEW AA
A
A
FIXTURE 1158
ITEM NO.
QTY REQD
PART NO.
DESCRIPTION
MATERIAL
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED
MATERIAL:
ALUM.
6061-
NEXT ASSY
USED ON
APPLICATION
AERTRON
HYPOTENUSE
POLARIZER PRISM
B
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A-
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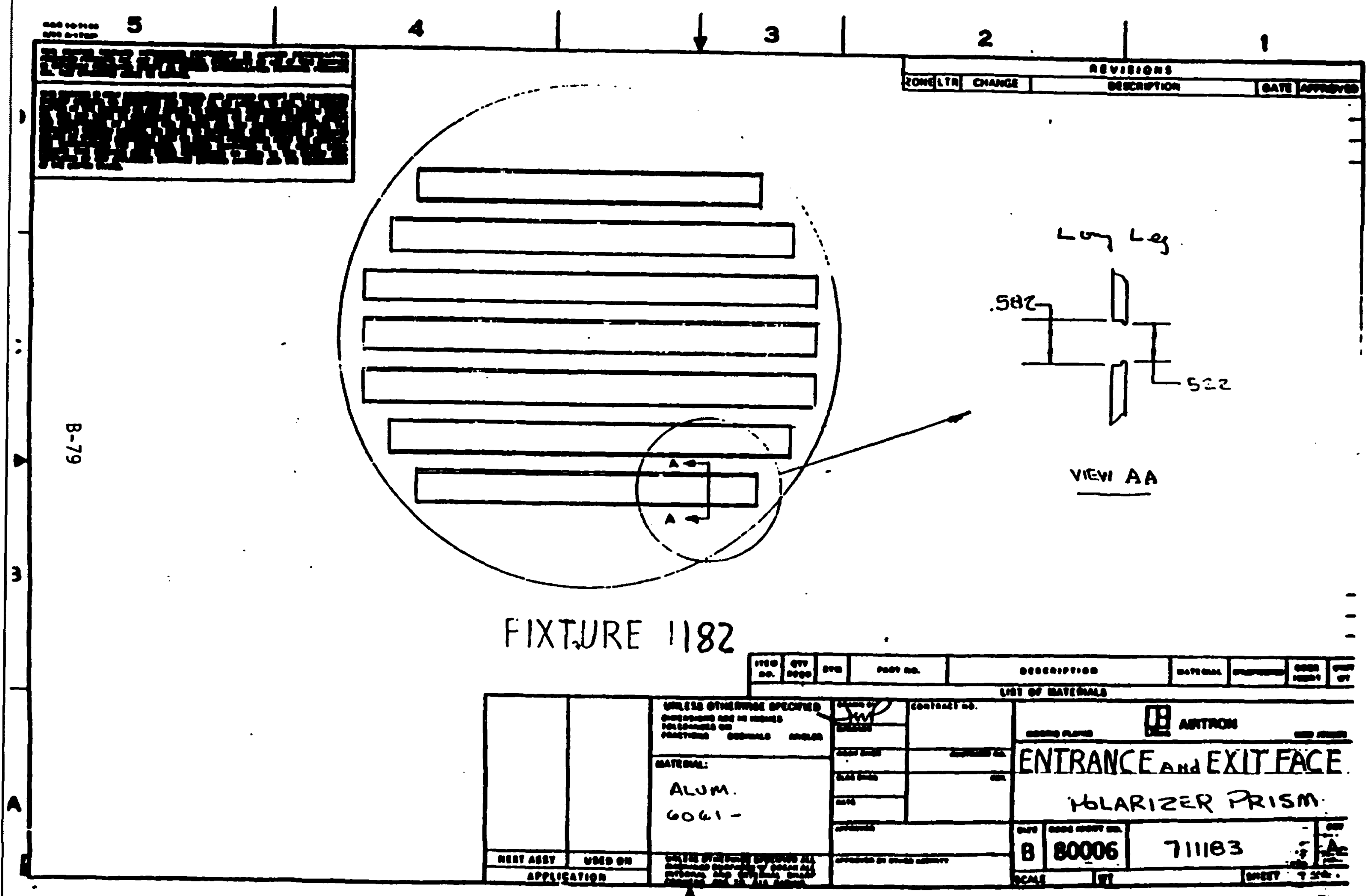
REVISIONS
ZONE LTR CHANGE DESCRIPTION DATE APPROVED
Long Leg.
.582
.522
VIEW AA
A
A
FIXTURE 1182
LIST OF MATERIALS
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QTY REQD
PART NO.
DESCRIPTION
MATERIAL
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED
MATERIAL:
ALUM.
6061-
CONTRACT NO.
AIRTRON
ENTRANCE AND EXIT FACE
POLARIZER PRISM
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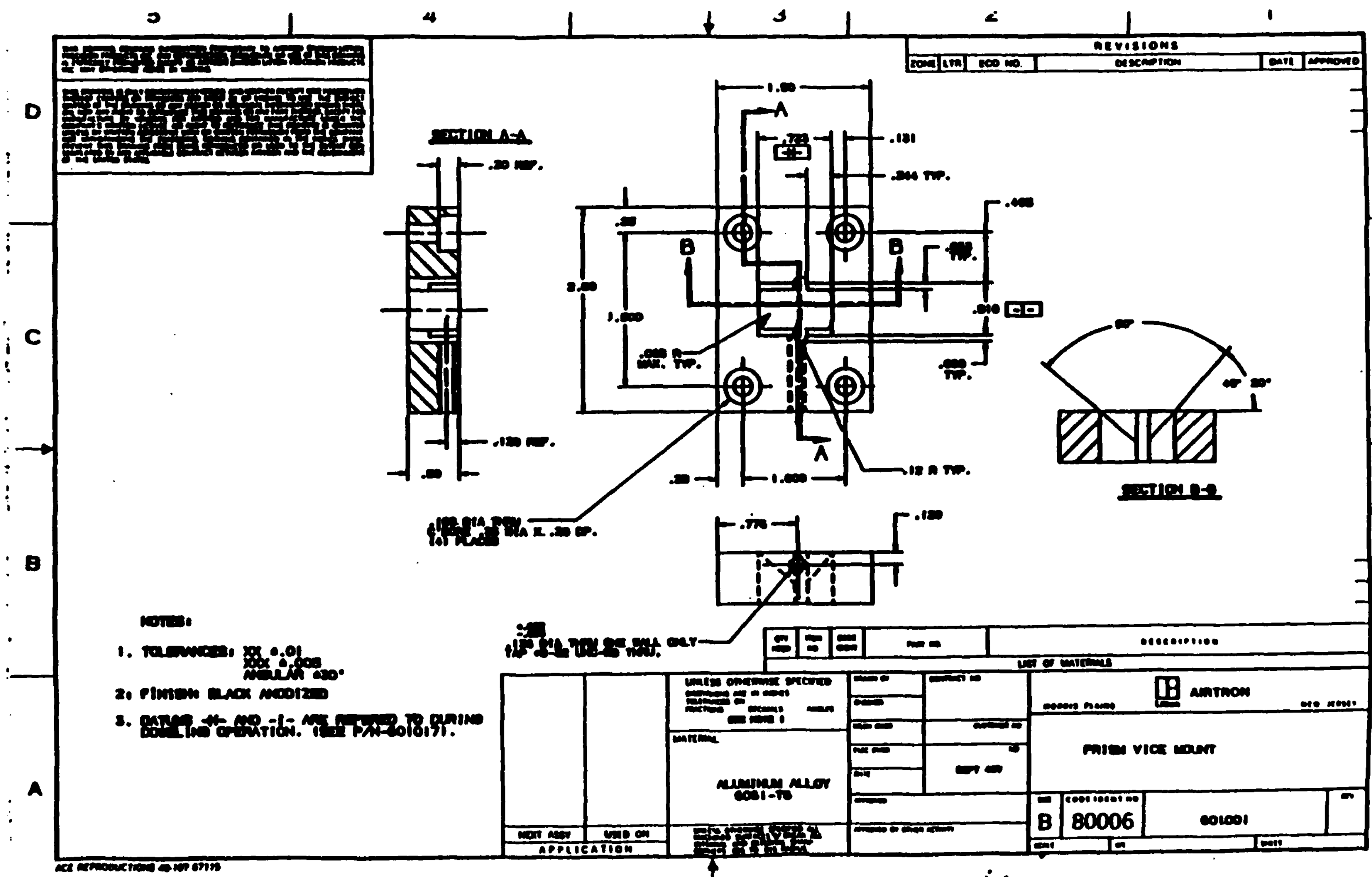
80006
711183
SCALE
SHEET


REVISIONS
ZONE LTR ECO NO. DESCRIPTION DATE APPROVED
SECTION A-A
SECTION B-B
NOTES:
1. TOLERANCES: XX ±.01
XXX ±.005
ANGULAR ±30'
2. FINISH: BLACK ANODIZED
3. DATUMS -H- AND -I- ARE REFERRED TO DURING DOWELING OPERATION. (SEE P/N-601017).
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED
MATERIAL
ALUMINUM ALLOY 6061-T6
NEXT ASSY USED ON
APPLICATION
AIRTRON
PRISM VICE MOUNT
B 80006 601001
ACE REPRODUCTIONS

APPENDIX C

MANUFACTURING FLOW CHART

29 JANUARY 1988

POLARIZER MANUFACTURING FLOW CHART